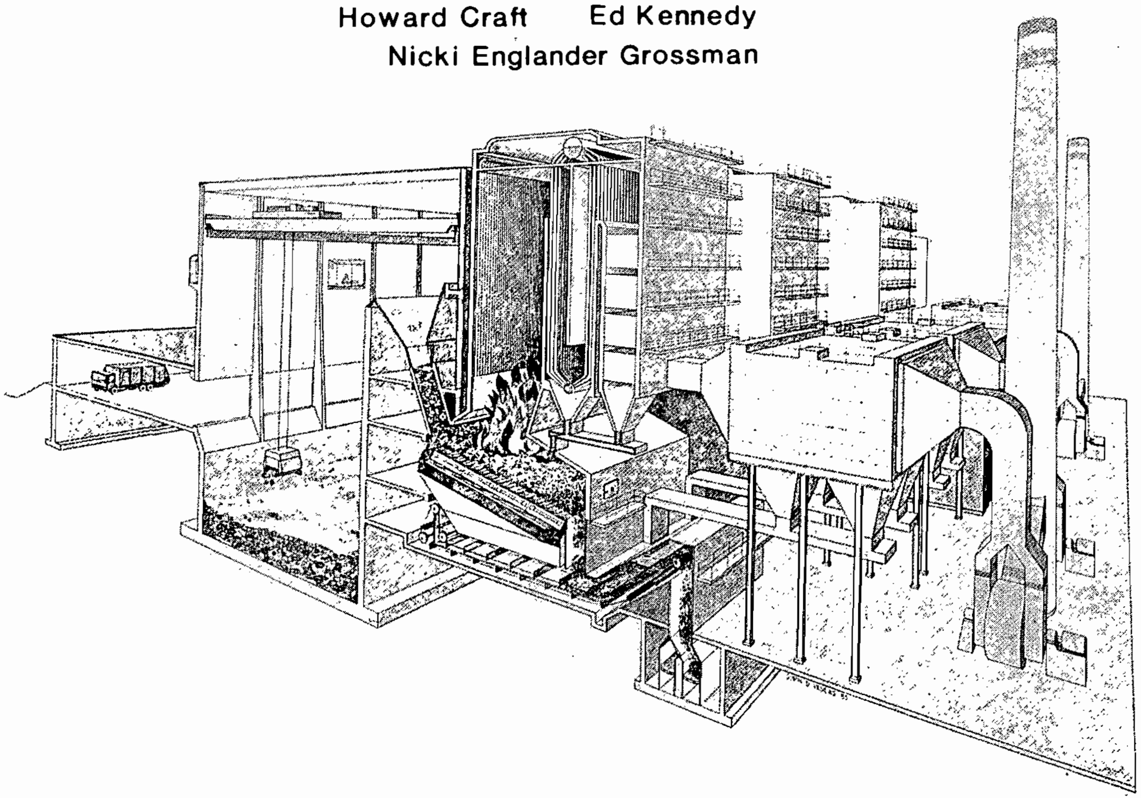
South Broward County Resource Recovery Project, Inc.

Solid Waste Energy Recovery Facility Application for Power Plant Site Certification

Volume III - Route 441 - Appendices

Submitted By
The Broward County
Board of County Commissioners

Scott I. Cowan, Chairman
Gerald Thompson, Vice Chairman
Marcia Beach Howard Forman
Howard Craft Ed Kennedy
Nicki Englander Grossman



Floyd T. Johnson, County Administrator
Thomas M. Henderson, Director, Resource Recovery Office

March 1985

MALCOLM PIRNIE

VOLUME III

LIST OF APPENDICES

APPendix 10.9

APPLICATION FILE NUMBER 060781739

FLORIDA DEPARTMENT OF ENVIRONMENTAL REGULATION

U.S. DEPARTMENT OF THE ARMY

JOINT APPLICATION FOR ACTIVITIES IN THE WATERS OF THE STATE OF FLORIDA
RESPONSE TO COMPLETENESS SUMMARY

SOUTHERN RESOURCE RECOVERY FACILITY
APPLICATION FILE NUMBER 060781739

WATER QUALITY SAMPLING PROGRAM CONDUCTED IN THE SOUTH FORK OF THE NEW RIVER

BROWARD COUNTY, FLORIDA
MAY 3, 1984

HAZEN AND SAWYER, P.C.
CZR, INCORPORATED
MALCOLM PIRNIE, INC.

TABLE 1

TIDAL FLUCTUATIONS

Time	*Reading
0730	762 mm
1103	890 mm
1216	980 mm
1511	1200 mm
1708	1050 mm
1846	920 mm
2010	800 mm
2235	860 mm
0219	1750 mm
0434	1150 mm

**Tides @ Andrews Avenue for 3/15/84

HIGH	LOW
0703	0138
1921	1334

**Information obtained from Fort Lauderdale News 3/14/84

*The reading was taken from the top of the survey stick to the water level. The stick was located on the west bank just north of sample location E.

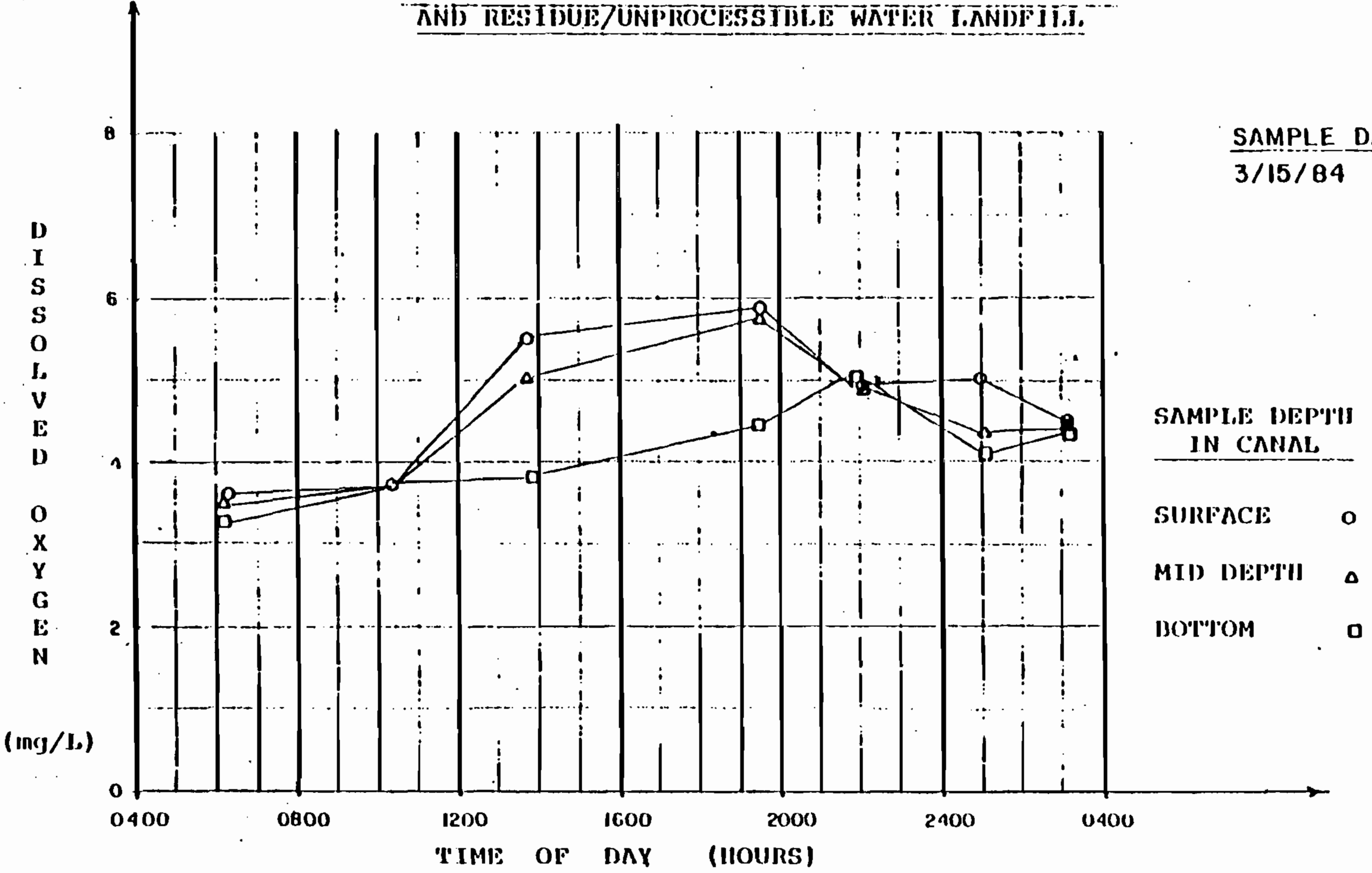
TABLE 2

AMBIENT WEATHER CONDITIONS

Time	Cloud Cover	Wind	Air Temperature
0705	15%	4-7kn from N.E.	21°C
1100	10%	2-4kn from N.E	23°C
1520	30%	5-7kn from N.E	26°C
2040	75%	3-5kn from N.E	23°C
2330	75%	5-10kn from N.E.	21°C
0200	75%	5-10kn from N.E.	20°C
0410	75%	4-7kn from N.E.	18°C

SURFACE WATER SAMPLING SITE A

SOUTHERN BROWARD RESOURCE RECOVERY FACILITY AND RESIDUE/UNPROCESSIBLE WATER LANDFILL

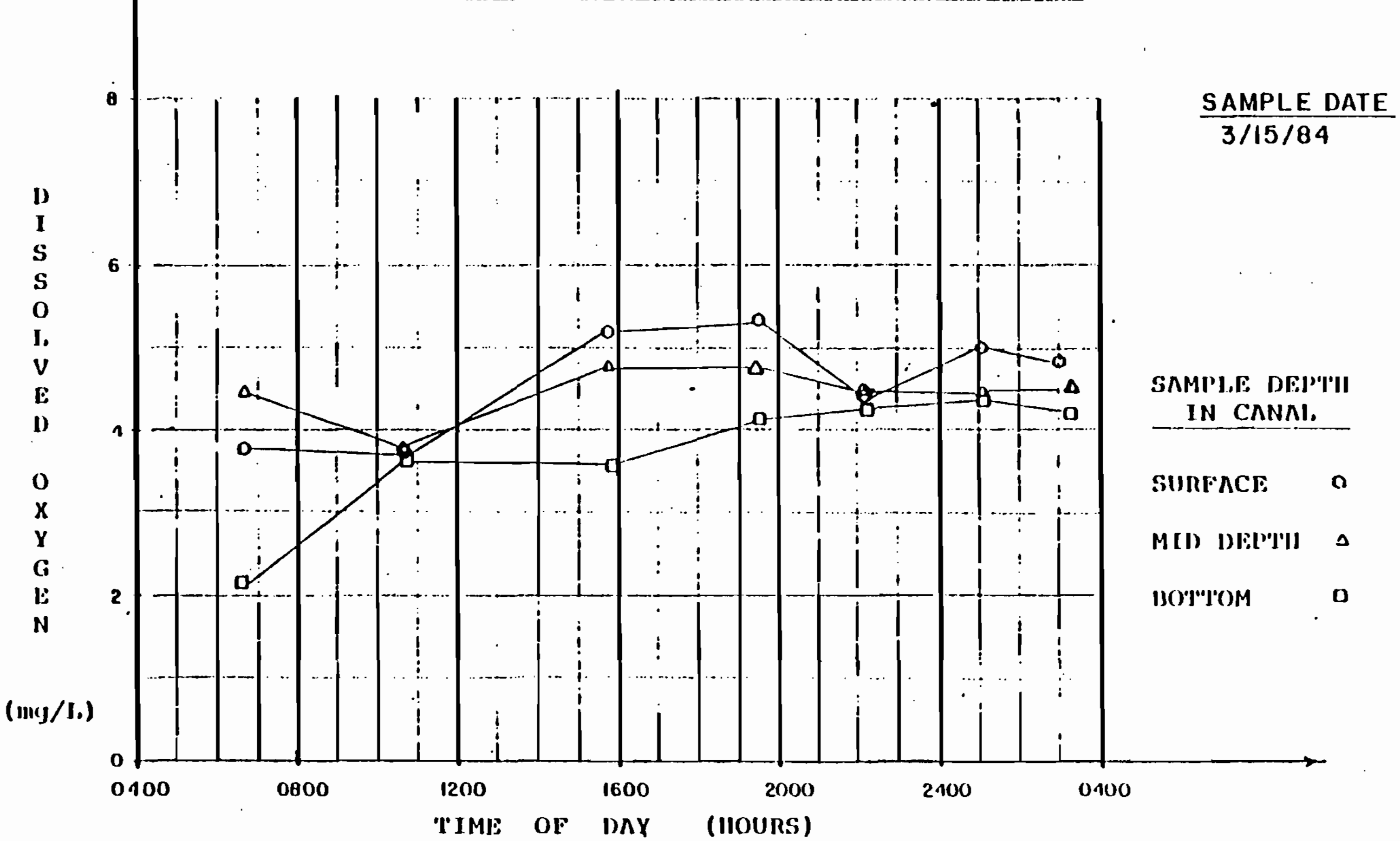


NOTE: Dissolved oxygen measurements were obtained using the Membrane Electrode Method as described in EPA manual "Methods for Chemical Analysis of Water and Wastes", 1979. The membrane was calibrated in the field using the Winkler Titration every 4 hours.

Figure 1

SURFACE WATER SAMPLING SITE B

SOUTHERN BROWARD RESOURCE RECOVERY FACILITY
AND RESIDUE/UNPROCESSIBLE WATER LANDFILL



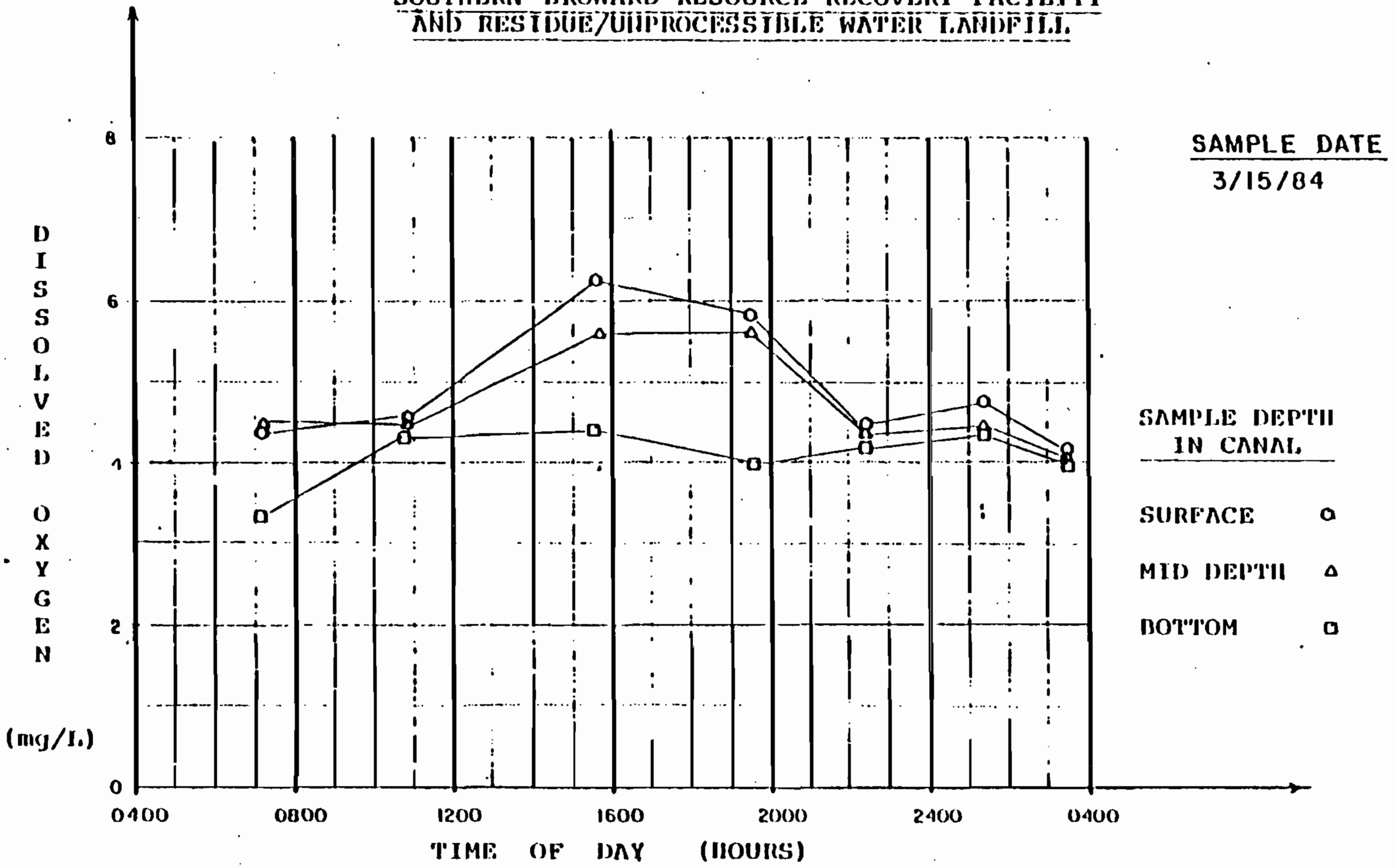
SAMPLE DATE
3/15/84

NOTE: Dissolved oxygen measurements were obtained using the Membrane Electrode Method as described in EPA manual "Methods for Chemical Analysis of Water and Wastes", 1979. The membrane was calibrated in the field using the Winkler Titration every 4 hours.

Figure 2

SURFACE WATER SAMPLING SITE C

SOUTHERN BROWARD RESOURCE RECOVERY FACILITY AND RESIDUE/UNPROCESSIBLE WATER LANDFILL



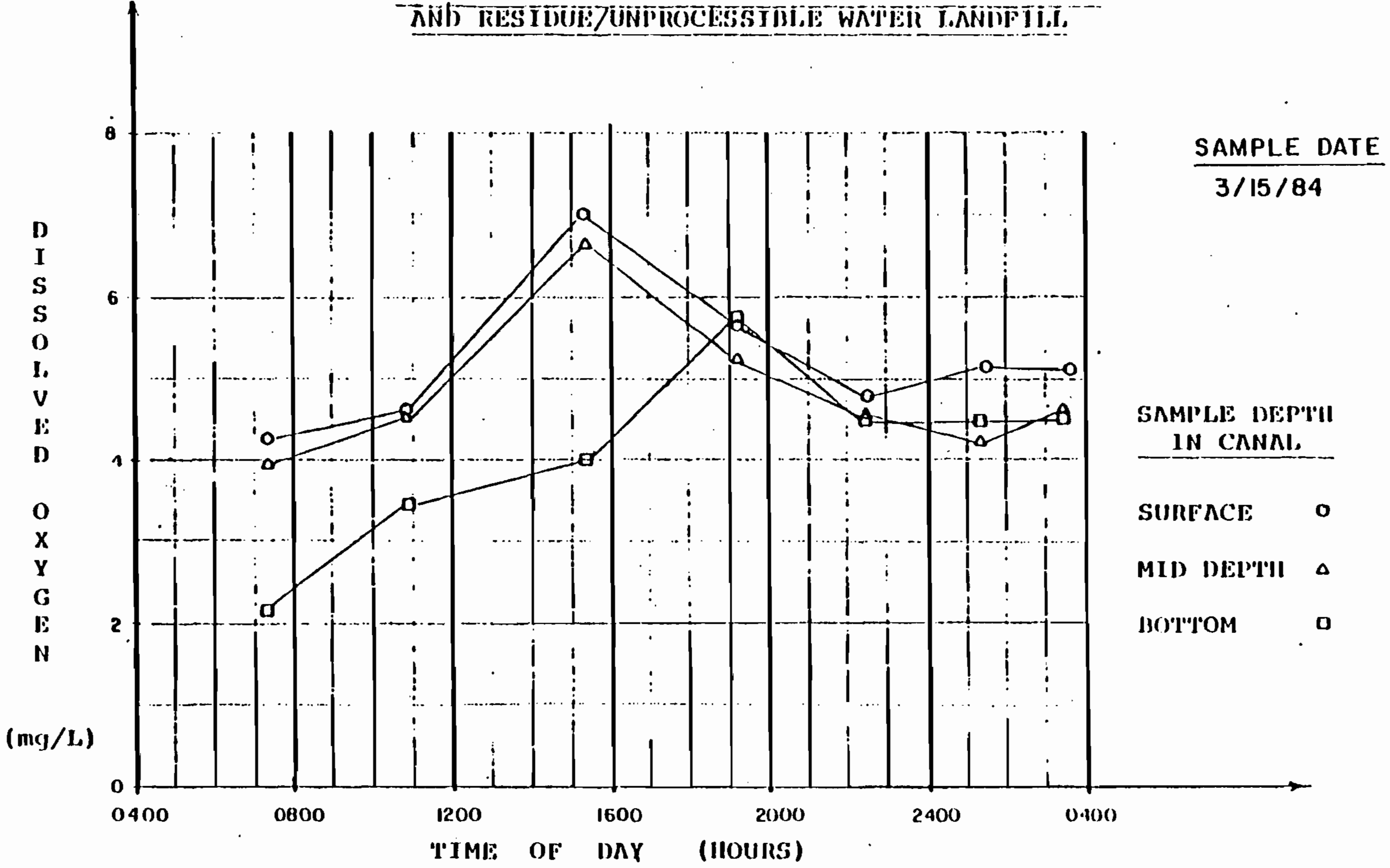
SAMPLE DATE
3/15/84

NOTE: Dissolved oxygen measurements were obtained using the Membrane Electrode Method as described in EPA manual "Methods for Chemical Analysis of Water and Wastes", 1979. The membrane was calibrated in the field using the Winkler Titration every 4 hours.

Figure 3

SURFACE WATER SAMPLING SITE D

SOUTHERN BROWARD RESOURCE RECOVERY FACILITY AND RESIDUE/UNPROCESSIBLE WATER LANDFILL

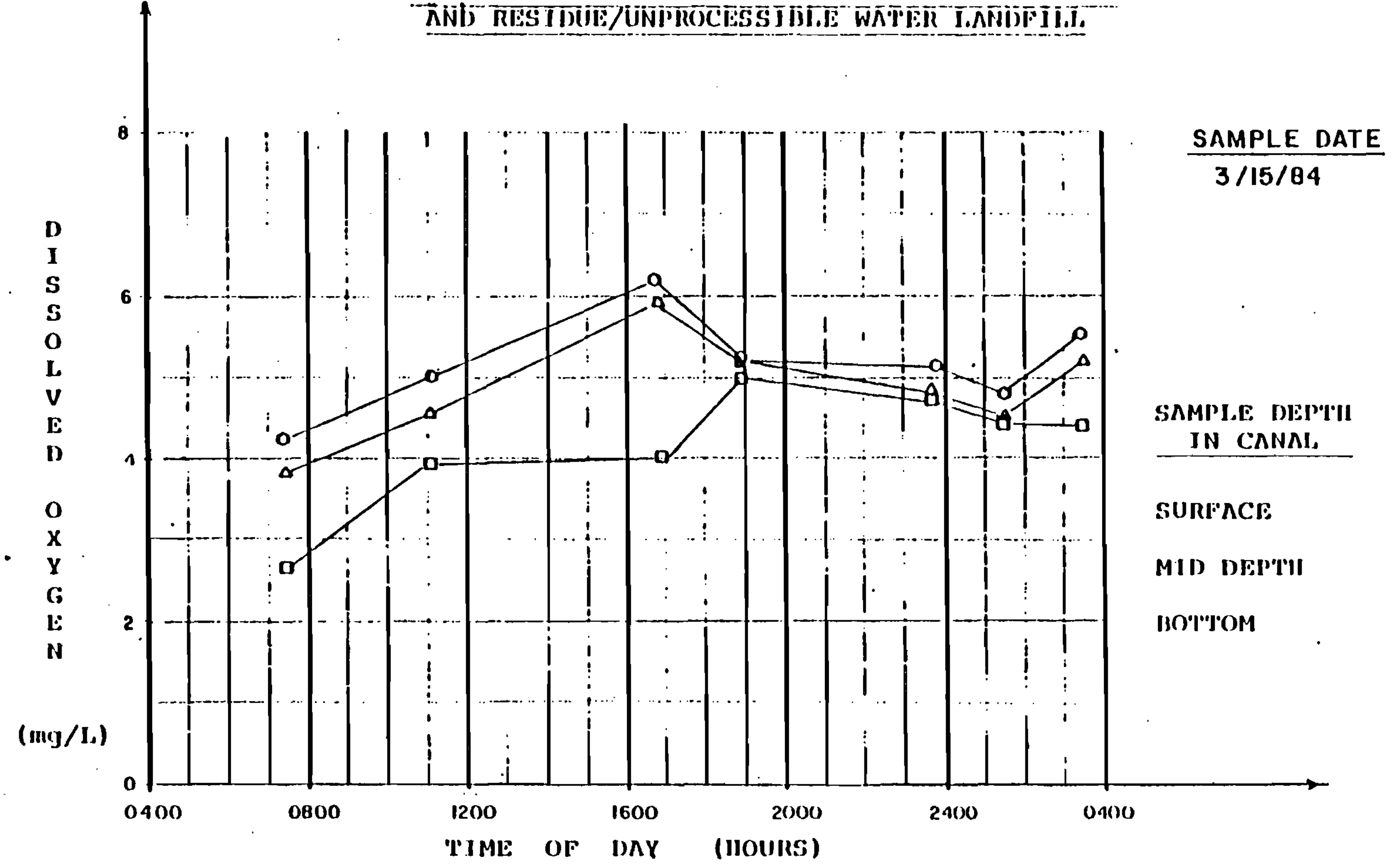


NOTE: Dissolved oxygen measurements were obtained using the Membrane Electrode Method as described in EPA manual "Methods for Chemical Analysis of Water and Wastes", 1979. The membrane was calibrated in the field using the Winkler Titration every 4 hours.

Figure 4

SURFACE WATER SAMPLING SITE E

SOUTHERN BROWARD RESOURCE RECOVERY FACILITY AND RESIDUE/UNPROCESSIBLE WATER LANDFILL

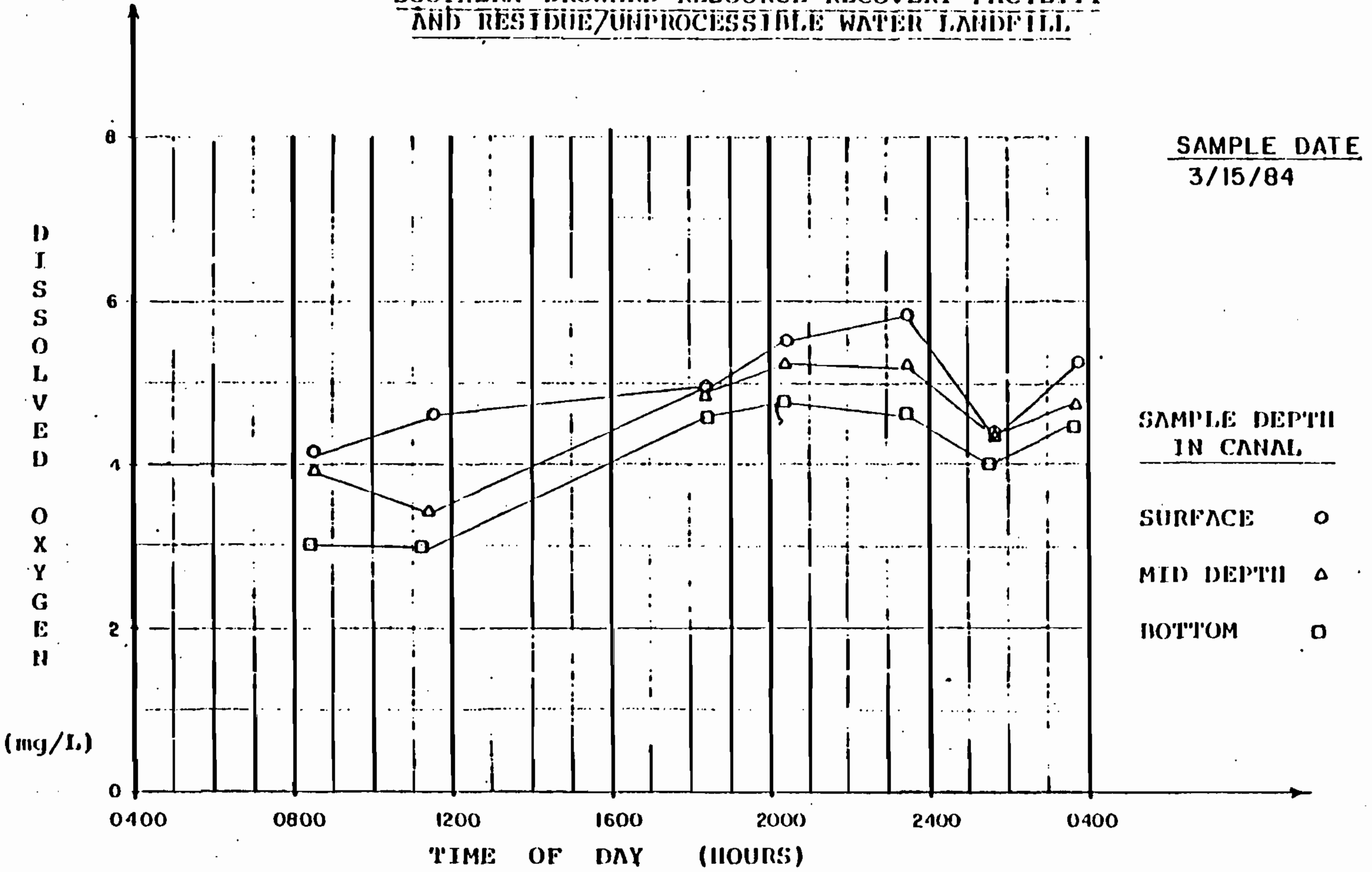


NOTE: Dissolved oxygen measurements were obtained using the Membrane Electrode Method as described in EPA manual "Methods for Chemical Analysis of Water and Wastes", 1979. The membrane was calibrated in the field using the Winkler Titration every 4 hours.

Figure 5

SURFACE WATER SAMPLING SITE F

SOUTHERN BROWARD RESOURCE RECOVERY FACILITY AND RESIDUE/UNPROCESSIBLE WATER LANDFILL

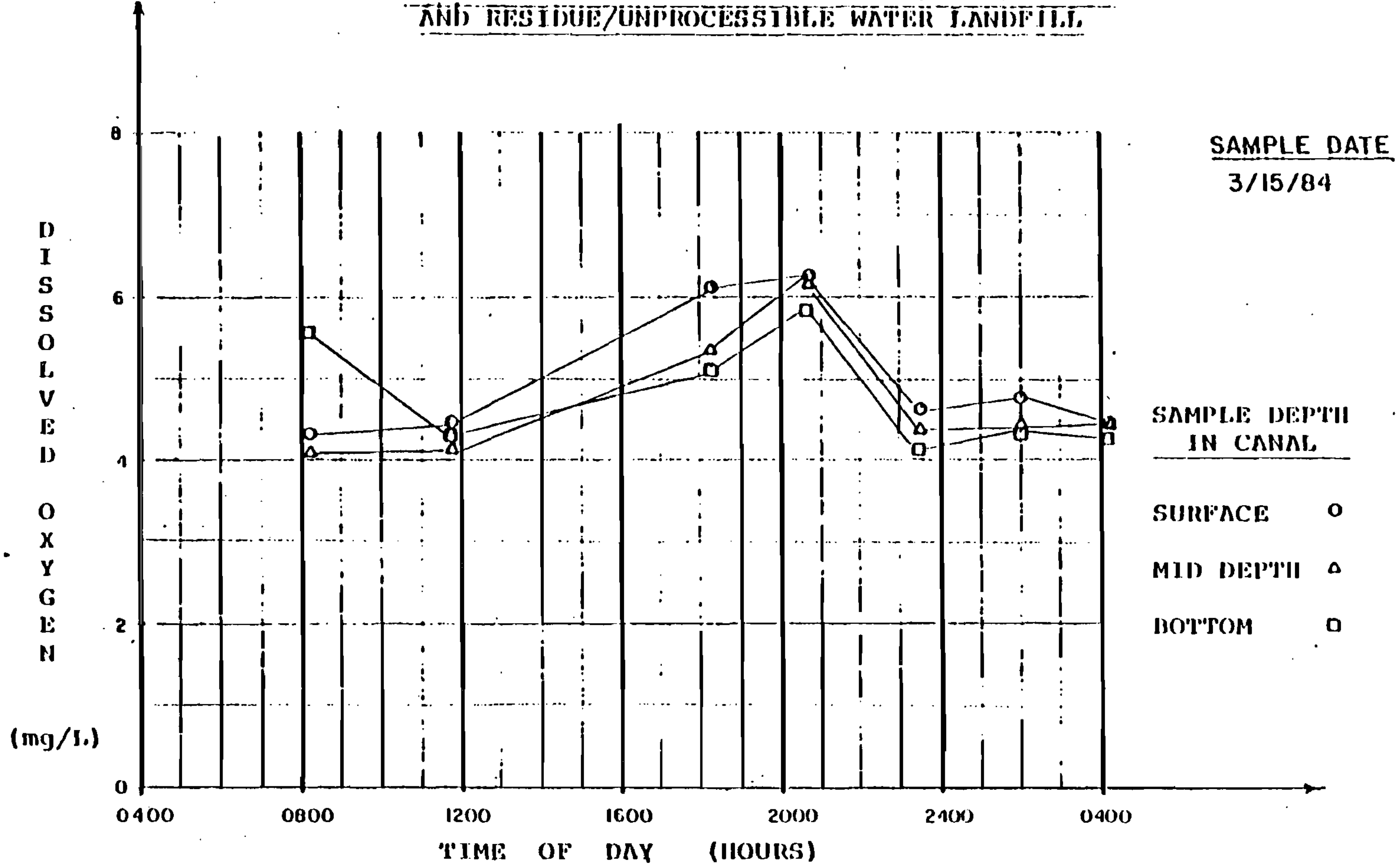


NOTE: Dissolved oxygen measurements were obtained using the Membrane Electrode Method as described in EPA manual "Methods for Chemical Analysis of Water and Wastes", 1979. The membrane was calibrated in the field using the Winkler Titration every 4 hours.

Figure 6

SURFACE WATER SAMPLING SITE G

SOUTHERN BROWARD RESOURCE RECOVERY FACILITY AND RESIDUE/UNPROCESSIBLE WATER LANDFILL



NOTE: Dissolved oxygen measurements were obtained using the Membrane Electrode Method as described in EPA manual "Methods for Chemical Analysis of Water and Wastes", 1979. The membrane was calibrated in the field using the Winkler Titration every 4 hours.

Figure 7

TABLE 3

Results of Dissolved Oxygen Monitoring

Sample Point	Date	Time	Depth	Dissolved Oxygen (mg/l)	Salinity (S0/00)	Temp. (°C)
A	3/15/84	0613	Bottom	3.3	0.02	24
		0615	Mid	3.5		
		0617	Surface	3.6		
B	3/15/84	0642	Bottom	2.2	2.0	23.8
		0644	Mid	4.5		
		0646	Surface	3.8		
C	3/15/84	0701	Bottom	3.4	2.0	23
		0703	Mid	4.5		
		0704	Surface	4.4		
D	3/15/84	0712	Bottom	2.2	2.2	24
		0713	Mid	4.0		
		0714	Surface	4.3		
E	3/15/84	0724	Bottom	2.7	1.8	29
		0725	Mid	3.9		
		0726	Surface	4.2		
F	3/15/84	0830	Bottom	2.9	2.0	23
		0831	Mid	3.9		
		0832	Surface	4.1		
G	3/15/84	0805	Bottom	5.6	7.0	24
		0806	Mid	4.1		
		0807	Surface	4.3		
A	3/15/84	1019	Bottom	3.8	2.0	24
		1020	Mid	3.8	1.0	
		1021	Surface	3.8	1.0	
B	3/15/84	1038	Bottom	3.6	5.0	24
		1039	Mid	3.8	0.8	
		1040	Surface	3.7	0.5	
C	3/15/84	1044	Bottom	4.3	5.5	24
		1045	Mid	4.4	1.0	
		1046	Surface	4.6	1.0	
D	3/15/84	1052	Bottom	3.5	5.2	24
		1053	Mid	4.5	1.1	
		1056	Surface	4.6	1.0	
E	3/15/84	1100	Bottom	3.9	4.9	24.5
		1102	Mid	4.5	1.0	
		1101	Surface	5.0	1.0	

Table 3 - Results of Dissolved Oxygen Monitoring

Sample Point	Date	Time	Depth	Dissolved Oxygen (mg/l)	Salinity (S0/00)	Temp. (°C)
F	3/15/84	1129	Bottom	2.9	2.5	24
		1130	Mid	3.4	1.5	
		1131	Surface	4.6	1.0	
G	3/15/84	1149	Bottom	4.3	3.0	24
		1151	Mid	4.1	2.9	
		1152	Surface	4.4	2.4	
A	3/15/84	1350	Bottom	3.9	1.2	25.5
		1350	Mid	5.1	0.9	
		1351	Surface	5.6	0.5	
B	3/15/84	1552	Bottom	3.5	6.8	24
		1551	Mid	4.8	0.9	
		1550	Surface	5.2	0.6	
C	3/15/84	1529	Bottom	4.4	5.0	25
		1528	Mid	5.7	1.5	
		1527	Surface	6.3	1.5	
D	3/15/84	1519	Bottom	4.0	4.9	24.5
		1518	Mid	6.7	2.0	
		1517	Surface	7.0	1.5	
E	3/15/84	1658	Bottom	3.9	3.8	24
		1657	Mid	5.9	2.0	
		1656	Surface	6.2	1.9	
F	3/15/84	1833	Bottom	4.6	2.0	24
		1834	Mid	4.9	1.9	
		1834	Surface	4.9	2.0	
G	3/15/84	1817	Bottom	5.2	6.8	24
		1816	Mid	5.4	4.8	
		1815	Surface	6.1	2.8	
A	3/15/84	1939	Bottom	4.5	0.5	23.5
		1939	Mid	5.8	0.5	
		1940	Surface	5.9	0.5	
B	3/15/84	1928	Bottom	4.1	2.1	24
		1928	Mid	4.8	1.0	
		1929	Surface	5.3	1.0	
C	3/15/84	1918	Bottom	4.0	1.5	24
		1919	Mid	5.7	1.4	
		1920	Surface	5.9	1.0	
D	3/15/84	1907	Bottom	5.8	1.5	24
		1908	Mid	5.2	1.9	
		1908	Surface	5.7	1.9	

Table 3 - Results of Dissolved Oxygen Monitoring

Sample Point	Date	Time	Depth	Dissolved Oxygen (mg/l)	Salinity (S0/00)	Temp. (°C)
E	3/15/84	1857	Bottom	4.9	2.0	
		1857	Mid	5.2	1.9	24
		1858	Surface	5.2	1.9	24
F	3/15/84	2021	Bottom	4.8	1.5	
		2021	Mid	5.3	1.5	24
		2022	Surface	5.5	1.5	
G	3/15/84	2038	Bottom	5.9	5.0	
		2038	Mid	6.3	4.0	28
		2039	Surface	6.3	3.0	
A	3/15/84	2200	Bottom	5.2	2.0	
		2201	Mid	5.0	1.0	25
		2202	Surface	5.0	0.5	
B	3/15/84	2212	Bottom	4.3	2.0	
		2212	Mid	4.4	1.0	25
		2213	Surface	4.4	0.5	
C	3/15/84	2219	Bottom	4.2	4.0	
		2220	Mid	4.4	2.5	25
		2220	Surface	4.4	1.0	
D	3/15/84	2226	Bottom	4.4	3.0	
		2227	Mid	4.5	2.0	
		2227	Surface	4.8	1.0	
E	3/15/84	2349	Bottom	4.8	3.5	
		2350	Mid	4.8	2.0	25
		2349	Surface	5.2	1.0	
F	3/15/84	2337	Bottom	4.6	1.5	
		2336	Mid	5.2	1.5	24
		2336	Surface	5.8	1.5	
G	3/15/84	2318	Bottom	4.2	6.5	
		2318	Mid	4.4	3.0	24
		2317	Surface	4.7	2.0	
A	3/16/84	0100	Bottom	4.2	0.1	
		0100	Mid	4.4	0.5	24
		0101	Surface	5.0	0.2	
B	3/16/84	0107	Bottom	4.4	2.5	
		0108	Mid	4.4	0.5	25
		0.08	Surface	5.0	0.5	

Table 3 - Results of Dissolved Oxygen Monitoring

Sample Point	Date	Time	Depth	Dissolved Oxygen (mg/l)	Salinity (S0/00)	Temp. (°C)
C	3/16/84	0115	Bottom	4.4	2.0	25
		0115	Mid	4.4	1.0	
		0116	Surface	4.3	1.0	
D	3/16/84	0122	Bottom	4.4	2.0	24
		0122	Mid	4.2	1.5	
		0123	Surface	5.2	1.0	
E	3/16/84	0127	Bottom	4.5	4.0	24
		0128	Mid	4.5	2.0	
		0128	Surface	4.8	1.5	
F	3/16/84	0139	Bottom	4.0	2.0	24
		0140	Mid	4.4	1.5	
		0140	Surface	4.4	1.5	
G	3/16/84	0154	Bottom	4.4	5.0	24
		0154	Mid	4.4	2.5	
		0155	Surface	4.8	2.2	
A	3/16/84	0308	Bottom	4.5	0.0	23.5
		0309	Mid	4.5	0.0	
		0309	Surface	4.5	0.0	
B	3/16/84	0316	Bottom	4.2	4.0	24
		0317	Mid	4.5	1.0	
		0317	Surface	4.8	0.5	
C	3/16/84	0324	Bottom	4.0	1.5	23.5
		0324	Mid	4.2	0.3	
		0324	Surface	4.2	0.1	
D	3/16/84	0330	Bottom	4.4	4.0	24
		0331	Mid	4.5	1.5	
		0331	Surface	5.1	0.9	
E	3/16/84	0336	Bottom	4.4	3.0	23
		0336	Mid	5.2	1.2	
		0337	Surface	5.5	1.1	
F	3/16/84	0349	Bottom	4.5	2.0	23.5
		0350	Mid	4.8	1.5	
		0350	Surface	5.3	1.5	
G	3/16/84	0406	Bottom	4.3	5.5	24
		0407	Mid	4.4	3.0	
		0407	Surface	4.4	1.9	

GEO TEC inc. 1602 CLARE AVENUE • WEST PALM BEACH, FL 33401 • 305/833-7280

INFORMA

ANALYSIS REPORT

HAZEN & SAWYER PC	CLIENT NAME AND ADDRESS
5950 WASHINGTON ST.	
HOLLYWOOD, FL. 33023	
3-15-84 1350 INC	DATE/TIME COLLECTED/BY
3-15-84 2200	DATE/TIME RECEIVED
SOUTHERN RRF & LANDFILL	LOCATION
WATER QUALITY SAMPLING	PURPOSE

PARAMETER	STORET #	10154 POINT A TOP	10155 POINT A MID	10156 POINT A BOTTOM	10157 POINT B TOP	10158 POINT B MID	10159 POINT B BOTTOM
BOD(5)	00310	4	4	3	3	2	2
NON FILTER RES	00530	7	5	9	13	24	2
OIL & GREASE	00556	42	<1	<1	<1	<1	<1
pH	00400	6.5	7.0	6.8	7.0	6.9	6.8
KJELDAHL NIROGEN	00625	2.33	2.24	3.22	3.22	2.69	2.15
TOTAL PHOSPHORUS	00665	1.71	8.20	2.30	1.12	1.71	1.71
LEAD	01051	0.004	0.004	0.004	<0.003	0.008	0.017
ZINC	01092	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004
MERCURY	71900	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
COPPER	01042	0.006	0.009	0.005	0.004	0.006	0.006
CADMIUM	01027	0.002	0.002	0.002	0.003	0.003	0.007
NITRATES	00630	0.40	0.39	0.40	0.38	0.37	0.36
IRON	01045	0.396	0.396	0.374	0.322	0.311	0.364
NICKEL	01067	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006
CHEM.O2 DEMAND	00340	71	88	71	62	71	79
TIME COLLECTED		1350	1350	1351	1552	1551	1550

DATE 4-17-84 BY

ID 86122

All concentrations are in mg/l

GEO TEC inc. 1602 CLARE AVENUE • WEST PALM BEACH, FL 33401 • 305/833-7280

INFORMA

ANALYSIS REPORT

HAZEN & SAWYER PC	CLIENT NAME AND ADDRESS
5950 WASHINGTON ST.	
HOLLYWOOD, FL. 33023	
3-15-84 1350 INC	DATE/TIME COLLECTED/BY
3-15-84 2200	DATE/TIME RECEIVED
SOUTHERN RRF & LANDFILL	LOCATION
WATER QUALITY SAMPLING	PURPOSE

PARAMETER	STORET #	10160 POINT C TOP	10161 POINT C MID	10162 POINT C BOTTOM	10163 POINT D TOP	10164 POINT D MID	10165 POINT D BOTTOM
BOD(5)	00310	3	3	11	2	4	3
NON FILTER RES	00530	7	7	180	4	18	8
OIL & GREASE	00556	4	<1	<1	<1	<1	<1
pH	00400	6.8	6.9	6.8	6.8	7.1	6.7
KJELDAHL NIROGEN	00625	2.51	2.15	1.80	1.98	2.15	2.42
TOTAL PHOSPHORUS	00665	1.42	1.42	4.07	1.71	2.60	2.30
LEAD	01051	0.010	0.021	0.065	0.013	0.010	0.027
ZINC	01092	<0.004	<0.004	0.008	<0.004	<0.004	0.004
MERCURY	71900	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
COPPER	01042	0.006	0.007	0.025	0.005	0.005	0.014
CADMIUM	01027	0.003	0.006	0.010	0.007	0.004	0.009
NITRATES	00630	0.37	0.37	0.19	0.36	0.39	0.34
IRON	01045	0.258	0.269	3.0	0.131	0.163	1.0
NICKEL	01067	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006
CHEM.O2 DEMAND	00340	71	79	97	71	79	97
TIME COLLECTED		1530	1535	1540	1635	1645	1655

DATE 4-17-84 BY

ID 86122

All concentrations are in mg/l

GEO TEC INC. 1602 CLARE AVENUE • WEST PA . BEACH, FL 33401 • 305/833-7290
MFORMA

ANALYSIS REPORT

HAZEN & SAWYER PC — CLIENT NAME AND ADDRESS
5950 WASHINGTON ST.
HOLLYWOOD, FL. 33023

3-15-84 1350 INC — DATE/TIME COLLECTED/BY

3-15-84 2200 — DATE/TIME RECEIVED

SOUTHERN RRF & LANDFILL — LOCATION

WATER QUALITY SAMPLING — PURPOSE

PARAMETER	STORET #	10166 POINT E TOP	10167 POINT E MID	10168 POINT E BOTTOM	10169 POINT F TOP	10170 POINT F MID	10171 POINT F BOTTOM
BOD(5)	00310	4	4	4	4	2	3
NON FILTER RES	00530	5	5	8	5	2	32
OIL & GREASE	00556	<1	<1	<1	<1	<1	<1
pH	00400	6.8	7.0	6.6	6.7	6.9	6.9
KJELDAHL NIROGEN	00625	2.06	2.33	1.89	2.15	2.95	3.67
TOTAL PHOSPHORUS	00665	1.71	6.73	2.01	4.07	2.30	5.84
LEAD	01051	0.014	0.017	0.015	0.016	0.014	0.012
ZINC	01092	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004
MERCURY	71900	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
COPPER	01042	0.004	0.003	0.008	0.004	0.005	0.008
CADMIUM	01027	0.006	0.009	0.007	0.008	0.007	0.007
NITRATES	00630	0.38	0.32	0.37	0.39	0.36	0.38
IRON	01045	0.131	0.110	0.374	0.258	0.163	0.575
NICKEL	01067	<0.006	<0.006	<0.006	<0.006	<0.006	<0.00
CHEM.O2 DEMAND	00340	71	62	62	62	53	467
TIME COLLECTED		1710	1715	1720	1740	1745	1750

DATE 4-17-84 BY Scott ID 86122

All concentrations are in mg/l

GEO TEC INC. 1602 CLARE AVENUE • WEST PALM BEACH, FL 33401 • 305/833-7230

ANALYSIS REPORT

HAZEN & SAWYER PC	CLIENT NAME AND ADDRESS
5950 WASHINGTON ST.	
HOLLYWOOD, FL. 33023	
3-15-84 1350 INC	DATE/TIME COLLECTED/BY
3-15-84 2200	DATE/TIME RECEIVED
SOUTHERN RRF & LANDFILL	LOCATION
WATER QUALITY SAMPLING	PURPOSE

PARAMETER	STORET #	10172 POINT G TOP	10173 POINT G MID	10174 POINT G BOTTOM
BOD(5)	00310	3	3	11
NON FILTER RES	00530	6	4	7
OIL & GREASE	00556	<1	<1	<1
pH	00400	6.9	7.0	7.1
KJELDAHL NIROGEN	00625	2.42	1.98	1.89
TOTAL PHOSPHORUS	00665	2.30	2.30	2.01
LEAD	01051	0.018	0.030	0.062
ZINC	01092	<0.004	<0.004	<0.004
MERCURY	71900	<0.001	<0.001	<0.001
COPPER	01042	0.005	0.005	0.008
CADMIUM	01027	0.008	0.008	0.015
NITRATES	00630	0.32	0.31	0.21
IRON	01045	0.128	0.150	0.217
NICKEL	01067	<0.006	<0.006	<0.006
CHEM.O2 DEMAND	00340	71	79	105
TIME COLLECTED		1805	1810	1815

DATE 4-17-84 BY ID 86122

All concentrations are in mg/l

BEST AVAILABLE COPY

TOTAL AND FECAL COLIFORM SAMPLING FOR SOUTH NEW RIVER CANAL

AMBIENT WEATHER CONDITIONS

Time	Cloud Cover	Wind	Air Temp
0930	60%	2-4 kn from S.E.	78°F
1030	85%	4-6 kn from S.E.	85°F
1100	80%	3-5 kn from S.E.	90°F

TIDAL FLUCTUATIONS

		[2]Tides @ Andrews Ave.	
Time	[1]Reading	High	Low
0925	37.69"	0943	0410
1100	35.63"	2213	1613

[3]TOTAL AND FECAL COLIFORMS

Sample Site	Time	Total	Fecal
A	1043	> 2000	1200
B	1030	1000	270
C	1015	500	70
D	1000	1000	240
E	0945	1200	330
F	0925	> 2000	320
G	0900	> 2000	420

SAMPLING DATE - MAY 1, 1984

NOTE: TOTAL and FECAL counts are in colonies per 100 ml.

[1] The reading was taken from the top of the survey stick to the water level. The stick was located on the west bank just north of sample location E.

[2] Information obtained from the Ft. Lauderdale Sun Sentinel on 5/1/84

[3] Samples were taken at mid-depth down the centerline of the stream. The samples were stored on ice and transported to Spectrum Laboratories for analysis.

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SOUTH FORK NEW RIVER

B.C.E.Q.C.B. SAMPLING PROGRAM

SAMPLE SITE 13

DATE	SAMPLE TIME	WATER TEMPERATURE °C	TURBIDITY JTU's	PH	SPECIFIC CONDUCTANCE micromho's/cm	FECAL STREP. #colonies/100ml	TOTAL COLIFORM #colonies/100 ml	FECAL COLIFORM #colonies/100ml
[illegible]	[illegible]	[illegible]	4.[illegible]	7.[illegible]	-9	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	4.7	7.0	-9	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	2.9	7.9	-9	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	2.4	7.5	-9	[illegible]	1700	370
12/07/81	[illegible]	21.0	4.1	8.1	-99	230	1200	370
[illegible]	[illegible]	[illegible]	2.9	7.7	-9999	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	-9999	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	-9999	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	-99	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	2.7	9.0	-99	[illegible]	1400	120
07/13/82	950	32.0	2.2	7.5	-99	270	520	120
[illegible]	[illegible]	27.0	[illegible]	7.5	-99	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	1.7	[illegible]	-99	[illegible]	[illegible]	720

DATE	SAMPLE TIME	DISSOLVED OXYGEN mg/l	7-DAY BOD mg/l	TOC mg/l	TKN-N mg/l	NH_3-N mg/l	ORGANIC NITROGEN mg/l	NO_2/NO_3-N mg/l	TOTAL PHOSPHORUS mg/l
[illegible]	[illegible]	2.72	2.7	26.7	1.64	0.31[illegible]	1.32	[illegible]	[illegible]
[illegible]	735	5.96	1.8	33.9	1.49	0.295	1.29	0.476	0.157
[illegible]	1000	[illegible]	[illegible]	[illegible]	[illegible]	0.094	1.04	[illegible]	[illegible]
09/21/81	1100	3.10	4.2	33.3	1.40	0.317	1.08	0.341	0.173
12/07/81	1000	3.74	4.[illegible]	19.4	1.29	0.126	1.16	0.140	0.120
[illegible]	910	3.75	2.7	21.3	1.47	0.440	[illegible]	0.436	[illegible]
[illegible]	[illegible]	[illegible]	3.7	[illegible]	1.44	0.167	1.27	0.437	[illegible]
[illegible]	730	3.00	1.0	22.2	1.20	[illegible]	0.78	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	1.0	-999.9	[illegible]	0.378	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	4.94	1.8	[illegible]	1.40	0.224	1.18	[illegible]	[illegible]
07/13/82	950	3.77	1.6	13.4	1.35	0.132	[illegible]	0.223	[illegible]
[illegible]	[illegible]	[illegible]	2.9	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

NOTE: -999.999 MISSING DATA CODE
MINUS VALUES DENOTES LESS THAN VALUE
B.C.E.Q.C.B. - BROWARD COUNTY ENVIRONMENTAL QUALITY CONTROL BOARD

SOUTH FORK NEW RIVER

B.C.E.Q.C.B. SAMPLING PROGRAM

SAMPLE SITE 20

DATE	SAMPLE TIME	WATER TEMPERATURE °C	TURBIDITY JTU's	PH	SPECIFIC CONDUCTANCE micromho's/cm	FECAL STREP. #colonies/ 100ml	TOTAL COLIFORM #colonies/ 100 ml	FECAL COLIFORM #colonies/ 100ml
11/17/80	1200	26.0	3.7	7.3	-9	200	1000	220
02/11/81	935	22.0	1.9	7.2	-1	-999	[illegible]	-999
06/22/81	1030	32.0	2.7	7.9	-9	300	2200	630
09/21/81	1130	29.0	2.6	7.7	-9	2000	170	750
12/07/81	1100	21.0	3.2	8.0	-99	400	3500	1300
02/16/82	930	25.0	2.8	7.7	-9999	240	1300	250
[illegible]	1040	30.0	2.4	7.6	-9999	200	1800	200
[illegible]	[illegible]	27.0	2.1	7.7	-9999	330	1300	170
[illegible]	[illegible]	23.0	2.6	7.4	-99	2200	2100	250
[illegible]	[illegible]	[illegible]	2.0	8.2	-99	320	[illegible]	170
07/13/83	1030	32.0	[illegible]	7.9	-99	440	200	99
10/11/83	950	27.0	2.5	7.5	-99	1470	1900	700
01/10/84	940	-99.9	1.0	7.7	-99	270	1700	210

DATE	SAMPLE TIME	DISSOLVED OXYGEN mg/l	7-DAY BOD mg/l	TOC mg/l	TKN-N mg/l	NH_3-N mg/l	ORGANIC NITROGEN mg/l	NO_2/NO_3-N mg/l	TOTAL PHORPHORUS mg/l
11/17/80	1200	9.85	5.3	30.2	2.17	0.770	1.40	0.162	0.133
12/11/81	935	3.45	2.2	26.0	1.50	0.312	1.19	0.432	0.114
[illegible]	[illegible]	-9.99	[illegible]	46.3	1.70	0.163	1.52	0.118	0.267
09/21/81	1130	3.00	5.4	21.6	1.56	0.449	1.11	0.702	0.133
12/07/81	1100	9.10	3.2	21.0	1.35	0.100	1.17	0.316	0.099
02/16/82	930	5.30	3.2	21.6	1.53	0.495	1.03	0.606	0.190
06/15/82	1010	4.57	3.2	22.2	1.52	0.179	1.34	0.318	0.120
10/25/82	1000	2.00	1.6	24.3	1.67	0.310	1.36	0.357	0.034
[illegible]	1100	4.70	1.2	-99.9	1.74	0.350	1.39	0.416	0.101
03/17/83	930	7.37	3.7	21.9	1.76	0.061	1.70	0.023	0.101
07/13/83	1030	4.67	2.4	21.0	1.50	0.099	1.47	0.176	[illegible]
10/11/83	950	[illegible]	1.5	22.0	1.75	0.342	1.31	0.177	[illegible]
01/10/84	940	2.91	1.3	-99.9	1.42	0.095	1.33	0.705	[illegible]

NOTE: -999.999 MISSING DATA CODE
MINUS VALUES DENOTES LESS THAN VALUE
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SOUTH FORK NEW RIVER

B.C.E.Q.C.B. SAMPLING PROGRAM

SAMPLE SITE 27

DATE	SAMPLE TIME	WATER TEMPERATURE °C	TURBIDITY JTU's	PH	SPECIFIC CONDUCTANCE micromho's/cm	FECAL STRIP. #colonies/ 100ml	TOTAL COLIFORM #colonies/ 100 ml	FECAL COLIFORM #colonies/ 100ml
11/17/80	[illegible]	25.0	7.9	7.4	340	4900	3300	970
12/03/80	1230	22.0	22.0	7.4	910	1000	2000	360
[illegible]	[illegible]	[illegible]	2.4	7.2	300	340	700	120
01/21/81	910	17.0	5.1	7.4	960	250	2200	370
02/11/81	1005	22.0	7.3	7.7	320	200	1200	1500
02/25/81	1255	23.0	4.5	7.5	680	220	19000	2300
03/11/81	1200	23.0	3.4	7.3	740	160	4400	1000
03/25/81	1000	20.0	4.6	20.0	820	110	12000	430
04/08/81	[illegible]	24.0	3.1	7.6	730	25	80	40
04/22/81	1110	27.0	1.4	7.4	730	100	50	10
05/06/81	1145	26.0	2.7	7.3	900	120	350	36
05/20/81	1120	27.0	1.7	7.8	750	420	300	91
06/09/81	1050	29.0	3.2	7.5	620	1900	5200	1900
06/24/81	1135	29.0	2.3	7.2	630	300	1300	340
[illegible]	[illegible]	-999.9	2.4	7.3	600	900	2000	1200
07/22/81	1150	29.0	2.4	7.4	610	920	1300	460
08/05/81	1205	29.0	2.6	7.4	650	4000	1700	200
08/19/81	1145	25.0	9.0	7.2	350	2300	2000	2400
09/21/81	955	28.0	3.5	7.5	490	1000	2300	1300
10/07/81	1140	29.0	3.2	7.3	720	220	3800	900
10/21/81	[illegible]	25.0	2.3	7.6	710	4200	730	200
11/03/81	1105	25.0	3.1	7.6	710	940	2000	320
11/18/81	1200	23.0	2.6	7.4	720	240	2000	310
12/07/81	910	20.0	1.2	7.3	-9999	220	1000	130
12/29/81	[illegible]	24.0	1.4	7.7	790	1000	16000	1600
01/12/82	1130	16.0	1.8	7.4	920	340	1400	170
01/27/82	1130	19.0	1.9	7.5	920	320	6000	3300
02/16/82	1020	23.0	2.2	7.7	-9999	200	2700	1000
03/02/82	940	21.0	0.9	7.6	300	230	830	360
03/16/82	1210	24.0	2.1	7.3	760	2900	5600	530
03/30/82	1200	24.0	1.8	7.9	820	120	17000	2500
04/13/82	950	24.0	1.8	7.9	940	140	1200	180
04/27/82	1205	25.0	2.9	7.2	510	1600	3300	1000
05/11/82	1200	26.0	1.0	7.7	730	120	1200	260
05/26/82	1215	27.0	3.0	7.5	690	960	8500	1900
06/15/82	1215	28.0	3.3	7.6	-9999	120	930	690
07/27/82	855	29.0	3.9	7.4	840	2000	2700	490
08/10/82	1115	29.0	4.2	7.6	910	1900	4100	1200
08/25/82	1010	29.0	3.2	7.3	900	1400	1300	900
09/07/82	915	28.0	4.2	6.8	800	1600	2200	640
09/29/82	1045	27.0	3.7	7.5	600	2800	7100	1200
10/13/82	1205	27.0	2.8	7.4	620	620	1400	260
10/25/82	1040	24.0	2.5	7.7	-9999	390	2200	200
11/08/82	1230	26.0	4.0	7.1	610	1200	3200	800
11/22/82	1240	25.0	4.6	7.4	650	22000	6300	600
12/06/82	1220	25.0	4.3	7.6	700	1600	5200	330
12/20/82	1235	20.0	1.8	7.5	700	370	1600	130
01/03/83	1145	24.0	1.7	7.1	740	2300	10000	190
01/24/83	1130	20.0	4.3	7.5	-99	32000	22000	7600
02/07/83	1200	22.0	3.8	7.6	640	33000	34000	1000
02/21/83	1150	-97.9	4.0	7.4	600	640	10000	750
03/07/83	1300	25.0	2.4	7.4	620	2600	3400	1100
03/21/83	1200	25.0	6.7	7.4	620	690	7600	300
04/04/83	1210	25.0	3.8	7.6	910	3000	4200	380
04/18/83	1230	24.0	2.8	7.6	720	600	5300	540
05/02/83	1230	26.0	3.0	8.0	690	480	660	160
[illegible]	[illegible]	28.0	1.7	8.0	890	150	340	91
05/31/83	1130	29.0	2.1	7.3	710	900	1300	230
06/13/83	1155	27.0	3.0	7.7	720	2200	4300	530
06/27/83	1135	27.0	2.4	7.3	540	300	2400	430
07/19/83	1055	32.0	4.2	7.8	750	460	930	290
08/01/83	1250	27.0	4.5	7.5	600	2400	4300	1020
[illegible]	[illegible]	[illegible]	[illegible]	7.8	[illegible]	[illegible]	[illegible]	[illegible]
08/30/83	1205	30.0	2.5	7.3	610	540	1200	180
09/12/83	1230	30.0	4.4	7.3	500	750	3400	230
09/27/83	1135	28.0	4.1	7.4	510	3100	2100	480
10/11/83	905	27.0	3.7	7.4	470	2000	2440	710
10/25/83	1205	27.0	2.7	7.4	600	730	1100	650
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
11/21/83	1135	25.0	[illegible]	7.7	730	240	1300	340
12/05/83	1220	27.0	1.4	7.4	710	200	1200	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	7.7	[illegible]	1200	1500	[illegible]
01/10/84	900	20.0	2.3	7.7	550	510	830	220
01/23/84	1215	20.0	7.8	7.8	790	360	1200	220
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
02/20/84	1130	22.0	[illegible]	7.6	710	6000	330	210
03/05/84	1140	20.0	[illegible]	7.7	730	1000	750	200

NOTE : -999.999 MISSING DATA CODE
MINUS VALUES DENOTES LESS THAN VALUE

[illegible]
BACTERIA COUNTS IN NO. OF COLONIES PER 100 ML SAMPLE
B.C.E.Q.C.B.- BROWARD COUNTY ENVIRONMENTAL QUALITY CONTROL BOARD

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SOUTH FORK NEW RIVER

B.C.E.Q.C.B. SAMPLING PROGRAM

SAMPLE SITE 27

DATE	SAMPLE TIME	DISSOLVED OXYGEN mg/l	7-DAY BOD mg/l	TOC mg/l	TKN-N mg/l	NH_3-N mg/l	ORGANIC NITROGEN mg/l	NO_2/NO_3-N mg/l	TOTAL PHORPHORUS mg/l
[illegible]	[illegible]	[illegible]	[illegible]	20.4	2.30	[illegible]	[illegible]	[illegible]	0.244
[illegible]	[illegible]	[illegible]	[illegible]	-999.9	[illegible]	0.373	1.30	0.326	[illegible]
01/07/91	1225	2.20	2.7	46.4	1.71	0.380	1.33	0.109	0.034
01/21/91	910	1.98	1.8	27.0	1.70	0.603	1.13	0.331	0.088
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	2.24	0.404	1.74	0.320	0.070
02/25/91	1255	2.34	2.1	20.4	1.59	0.413	1.18	0.029	0.174
03/11/91	1200	1.90	2.6	-999.9	2.30	0.590	1.79	0.401	0.165
03/25/91	1000	4.37	2.3	26.1	1.64	0.364	1.23	0.382	0.242
04/08/91	1105	5.35	2.8	30.6	1.75	0.094	1.67	0.512	0.072
04/22/91	1110	4.45	1.6	27.1	1.70	0.077	1.62	0.540	0.104
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	2.00	[illegible]	[illegible]	[illegible]	0.170
05/20/91	1120	4.97	3.8	26.6	1.71	0.065	1.64	0.219	0.161
06/10/91	1300	1.37	3.7	70.2	2.64	0.740	1.90	0.297	0.437
[illegible]	[illegible]	[illegible]	3.7	25.7	1.73	0.400	1.32	0.170	0.106
07/08/91	1135	3.18	4.8	28.3	1.84	0.562	1.28	0.276	0.330
07/22/91	1150	1.35	3.8	32.7	2.08	-999.999	-999.99	0.258	0.216
[illegible]	[illegible]	[illegible]	2.9	26.2	2.50	0.764	1.34	0.186	0.250
08/19/91	1140	1.37	5.2	25.2	2.50	0.574	1.93	0.035	0.333
[illegible]	950	3.30	6.1	27.0	2.40	0.566	1.35	0.263	0.209
10/07/91	1140	1.37	3.6	20.6	2.12	0.656	1.46	0.270	0.168
10/21/91	1110	2.77	3.3	25.8	1.71	0.343	1.37	0.386	0.105
[illegible]	1135	2.07	4.2	25.7	2.23	0.791	1.44	0.354	0.270
[illegible]	[illegible]	2.17	3.9	22.6	1.92	0.458	1.46	0.534	0.179
[illegible]	910	1.87	5.0	22.7	1.38	0.506	1.37	0.477	0.165
[illegible]	1210	3.08	3.4	26.9	-###.##	0.330	-###.##	0.437	0.103
[illegible]	1130	2.28	4.0	25.1	1.80	-###.###	-###.##	0.407	0.112
[illegible]	1130	2.35	5.0	31.4	1.82	-###.###	-###.##	0.480	0.125
02/24/92	1020	2.10	5.6	24.1	1.85	0.581	1.27	0.424	0.152
[illegible]	940	2.30	4.5	34.0	1.68	0.425	1.26	0.429	0.099
[illegible]	1210	4.63	4.2	30.4	1.67	0.257	1.40	0.444	0.121
[illegible]	1200	3.70	4.4	26.8	1.95	0.475	1.30	0.425	0.150
[illegible]	950	3.17	4.3	25.3	1.61	0.201	1.41	0.476	0.112
04/27/92	1205	1.23	4.6	26.8	2.61	1.100	1.51	0.340	0.337
05/11/92	1200	4.24	2.9	30.9	1.84	0.439	1.40	0.467	0.173
[illegible]	[illegible]	1.25	2.2	25.3	2.43	0.846	1.58	0.225	0.232
[illegible]	1215	3.04	3.3	26.1	2.03	0.463	1.62	0.348	0.157
[illegible]	955	1.03	1.3	22.9	1.92	0.412	1.51	0.172	0.160
08/10/92	1113	2.21	1.6	29.7	1.71	0.329	1.38	0.214	0.146
08/25/92	1010	1.44	2.8	28.4	1.94	0.405	1.54	0.211	0.132
[illegible]	915	1.20	1.5	29.2	1.77	0.329	1.44	0.153	-0.020
[illegible]	1045	1.10	2.0	26.2	2.57	0.983	1.59	0.326	0.232
10/13/92	1205	2.75	2.5	23.7	2.03	0.507	1.52	0.480	0.163
10/26/92	1040	2.20	1.7	25.3	1.81	0.310	1.50	0.499	0.196
[illegible]	1230	-99.99	1.2	31.9	2.10	0.522	1.58	0.548	0.176
11/22/92	1240	1.88	3.4	27.9	2.44	0.714	1.73	0.611	0.209
12/06/92	1220	3.45	2.0	24.4	2.14	0.491	1.65	0.585	0.263
[illegible]	1225	4.30	1.6	27.3	1.55	0.297	1.25	0.629	0.128
01/03/93	1145	2.23	1.7	27.2	1.88	0.157	1.72	0.578	0.149
01/24/93	1130	2.08	1.6	-99.9	2.15	0.803	1.35	0.576	0.264
02/07/93	1200	3.42	2.2	-99.9	2.22	0.715	1.50	0.703	0.263
02/21/93	1150	3.15	1.8	24.9	2.00	0.637	1.36	0.766	0.173
03/07/93	1300	3.20	1.5	23.5	1.95	0.454	1.50	0.685	0.158
[illegible]	[illegible]	3.25	2.3	25.7	2.10	0.528	1.57	0.539	0.209
04/04/93	1210	3.42	2.6	25.5	2.32	0.605	1.72	0.553	0.212
04/18/93	1230	3.30	2.3	31.5	2.24	0.575	1.66	0.520	0.203
[illegible]	1230	7.24	4.0	30.2	1.99	0.074	1.92	0.424	0.130
05/17/93	950	6.00	1.3	25.5	1.77	-0.050	1.77	0.329	0.082
05/31/93	1135	2.32	2.8	32.7	2.14	0.464	1.68	0.411	0.272
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
06/27/93	1135	2.31	3.3	24.0	2.33	0.675	1.70	0.626	0.209
07/19/93	1055	5.16	11.9	35.5	2.45	-0.050	2.45	0.333	0.102
[illegible]	[illegible]	1.30	3.1	26.0	2.43	0.657	1.77	0.262	0.275
08/15/93	1230	2.10	2.8	26.3	2.09	0.441	1.65	0.293	0.166
08/30/93	1205	1.49	2.2	25.2	2.13	0.626	1.54	0.281	0.199
[illegible]	[illegible]	[illegible]	[illegible]	-99.9	2.50	[illegible]	1.61	[illegible]	[illegible]
09/27/93	1155	1.79	2.2	-99.9	2.52	0.870	1.62	0.326	0.217
10/11/93	905	1.26	1.4	24.2	1.90	0.460	1.44	0.475	0.166
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.541	1.41	[illegible]	[illegible]
11/07/93	1220	2.66	2.1	27.3	1.96	0.342	1.60	0.598	0.103
11/21/93	1130	3.00	2.1	28.6	1.55	0.223	1.33	0.643	0.099
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
12/20/93	1210	2.77	2.7	28.3	2.41	0.737	1.67	0.624	0.237
[illegible]	900	2.26	1.4	-99.9	1.35	0.221	1.13	0.787	0.151
[illegible]	[illegible]	[illegible]	1.5	-99.9	1.74	0.215	1.52	[illegible]	[illegible]
02/06/94	1200	3.00	2.7	-99.9	1.81	0.353	1.46	0.510	0.105
02/20/94	1150	4.02	[illegible]	-99.9	1.72	0.203	1.50	0.503	0.120
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

NOTE : -999.999 MISSING DATA CODE

MINUS VALUES DENOTES LESS THAN VALUE

ALL CONCENTRATIONS IN MILLIGRAMS PER LITER

B.C.E.Q.C.B. - BROWARD COUNTY ENVIRONMENTAL QUALITY CONTROL BOARD

Appendix 10.10

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1.0 AMBIENT AND PREDICTED NOISE LEVELS

1.1 Overview

The following methodology was used to best project noise levels which will occur at the property lines of the resource recovery site:

1. Ambient noise levels at property lines were measured and recorded.
2. Based on the type and extent of equipment which is expected to be in operation at the facility and their associated noise levels, noise generated through the operation of the resource recovery facility and residue/unprocessable waste landfill was calculated.
3. The attenuation of noise over distance was factored into calculations of projected noise levels at property lines a given distance from the point of noise generation.
4. Noise levels measured at the property lines of a comparable facility, the Pinellas County Refuse-to-Energy Facility in St. Petersburg, Florida, were compared to these projected levels.

These methods and resulting findings are discussed in further detail in the sections that follow. Section 3 compares projected levels with those mandated in applicable regulations.

1.2 Ambient Levels

A recent inspection of the site indicated that noises present were generated by highway traffic on Routes 441 and 84 and from low-altitude commercial aircraft utilizing the east-west runway of the Fort Lauderdale-Hollywood International Airport. The runway is 10,000 feet east of the eastern side of the central section of the site.

Average ambient noise level readings around the accessible perimeter of the site, as measured on February 23, 1984 both in mid-afternoon and at 9 p.m., using a Simpson 886 Type

2 Sound Level Meter calibrated to OSHA standards at the site, under clear skies and with very little or no wind, ranged from 50 dB(A) to 55 dB(A) (Table 1). The higher readings were taken at the perimeter of the property on the west and north sides, close to the highways (Figure 1).

Noise excursions generated from large trucks on the highways and from aircraft taking off from the Fort Lauderdale-Hollywood International Airport caused dB(A) readings in the high 80's. Both sources, however, are exempt under the Code of Regulations Section 27-7.06 (see Section 2.2).

1.3 Noise Generation

Noise at the southern resource recovery facility and residue/unprocessable waste landfill will be generated in the operation of process equipment, air pollution control equipment, waste transfer trucks, and landfilling equipment. Table 2 is a summary of expected noise level readings from applicable equipment. Details are elaborated upon below.

Operation of the resource recovery facility will result in noises being generated from the following pieces of equipment and machinery inside or around the facility: overhead refuse-handling cranes, a steam turbine, a steam turbine steam exhaust condenser, various pumps, ash and residue conveyors, and the steam condenser water cooling tower fans.

The exact model and specifications (i.e. horsepower, sound rating) of equipment to be used will be finalized by the chosen Contractor for the facility. In any case, the equipment used will not generate unusually high noise levels or higher levels than those associated with equipment used at similar facilities.

The noises generated inside the facility structure(s) will be contained and attenuated by walls and roofing. It is anticipated that all equipment, except the steam condenser

TABLE 1

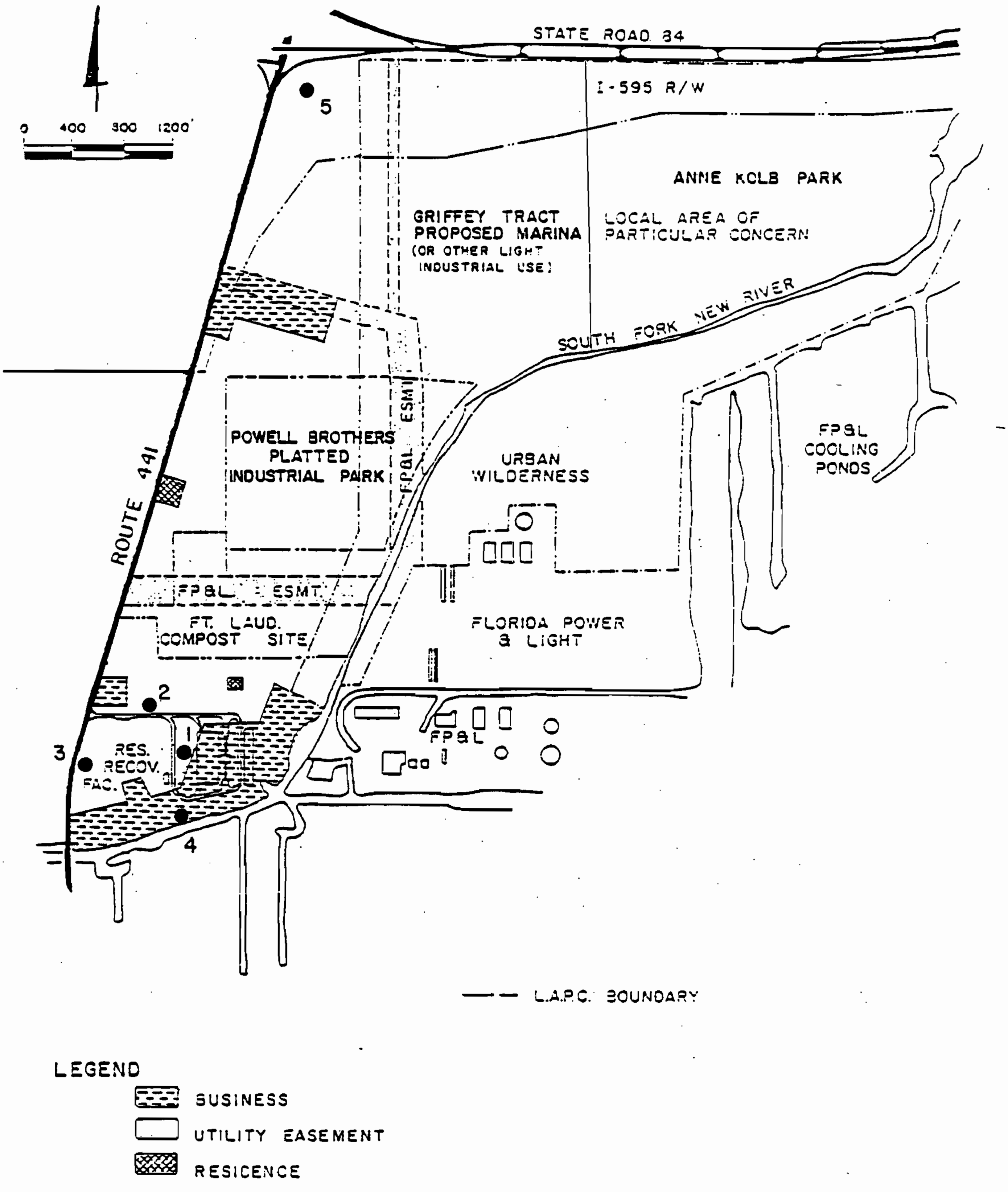
AVERAGE AMBIENT NOISE READINGS
February 23, 1984

Site	Time	Average (dB(A))
1	2:30 PM	55
	9:00 PM	52
2	2:30 PM	55
	9:00 PM	51
3	2:30 PM	55*
	9:00 PM	52.5
4	2:30 PM	51
	9:00 PM	50
5	2:30 PM	55*
	9:00 PM	53

*85 dB(A) with heavy constant vehicular and truck traffic.

Note: In all locations, low flying commerical aircraft gave readings from 70 dB(A) to 85 dB(B).

FIGURE 1



BROWARD COUNTY

RESOURCE RECOVERY

AMBIENT NOISE READING
LOCATIONS

TABLE 2

NOISE GENERATION BY OPERATING EQUIPMENT

Equipment	Location of Equipment	Noise Level @ 50 ft (dB(A))
Overhead refuse-handling crane	inside facility	Note (1)
Steam turbine	inside facility	Note (1)
Steam exhaust condenser	adjacent to facility	Approximately 53[2]
Pumps	inside facility	Note (1)
Ash and Residue Conveyors	inside facility	Note (1)
Water cooling tower fans	adjacent to facility	Approximately 42[2]
Refuse/transfer vehicles	on roads between site entrance and resource recovery facility	80[3]
Residue/unprocessable waste vehicles	on roads between site entrance, resource recovery facility, and landfill	80[3]
Dozers, compactors, graders	at landfill	80[3]

Notes

1. By virtue of containment in buildings, and noise attenuation by building materials, noise generated by this equipment will be essentially undetectable at property lines.

2. Noise level calculated by taking reading from the Pinellas County facility and increasing noise level reading by 6 dB(A) for every halving of distance between noise source and point of measurement (See Section 1.4).

3. Sources: 1. "Industrial Noise and Vibration Control" by Irwin and Graf. Prentice-Hall, Inc., 1979.

   2. "Handbook of Noise Control," 2nd Edition, Edited by Cyril M. Lewis, PhD., McGraw-Hill Book Co., 1979.

water cooling tower fans, will be located inside the facility building(s).

On-site trucking noise will be generated by refuse-filled collection trucks, by transfer vehicles bringing refuse into the facility, and by these same trucks/vehicles exiting the resource recovery facility. Heavy duty trucks hauling residue/unprocessable wastes from the resource recovery facility to the landfills will also generate on-site noise. In addition, landfilling operations will require use of tractor type dozers, compactors and graders. Much of the noise mentioned will be generated in conjunction with landfill operations. It is important to note that the type of waste to be landfilled (ash residue) and soil of the area itself acts as a buffer to absorb noise generated from such activity.

1.4 Noise Attenuation

Increasing distance from a noise source to the point of measurement is the most practical means of abatement of that noise. Specifically, for each doubling of distance from a single point noise, the noise level drops by 6 dB(A). Thus, if noise level meter readings are taken at 50 feet from the point source, at 100 feet the noise levels drop by 6 dB(A), at 200 feet, by 12 dB(A), and so on. The following table indicates these relationships in terms of various point source noise levels:

Noise Level in dB(A)'s at Various Distances from the Point Source

dB(A)'s 50' from Point Noise Source	100'	200'	300'	400'	800'	1600'
65	59	53	50	47	41	-
70	64	58	55	52	46	40
75	69	63	60	57	51	45
80	74	68	65	62	56	50

There are additional attenuation factors which, though difficult to quantify, will undoubtedly reduce noise levels through absorption. These factors include vegetation, the ash residue in the landfill, and the structures on the site. Direction and dispersion of the sound also has an affect on the ambient noise levels. Sounds produced at ground level are generally absorbed at a far greater rate than sounds produced in the air. For the purpose of this permit, these factors are not taken into account. As a result, the projections of noise levels are conservative and true levels can be expected to be somewhat lower than concluded herein.

1.5 Predicted Noise Levels at Boundaries

A review of Figure 2 (Southern Site Zoning) in conjunction with Figure 3 (Conceptual Development and Environmental Enhancement Plan for the Route 441 Site) shows that of the areas surrounding the site, industrial, business, and residential zones to the west and south appear most sensitive to potential noise. On the east and the north sides of the site, there will be extensive open spaces occupied by either the Interstate 595 interchange, the Anne Kolb County Park, or Florida Power & Light facilities. Figure 4 shows the zoning classifications and projected noise levels at sensitive boundaries. Below is a discussion of these projections.

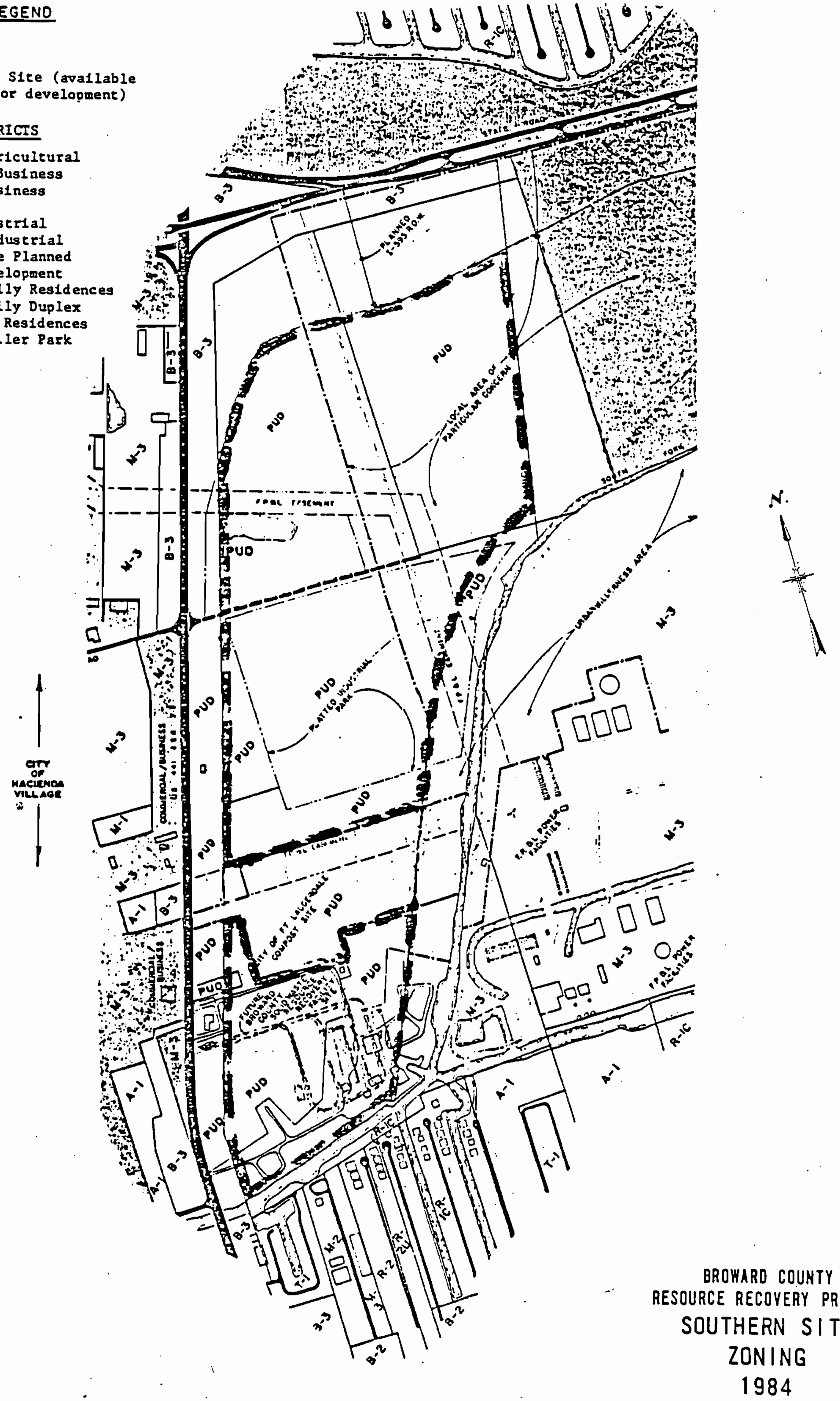
On the west side of the site, there will be a 200 foot setback on the east side of Route 441. The setback will be enriched with extensive landscaping which will include high trees to help buffer noises from facility operations. The Route 441 right-of-way is 100 feet wide. Thus, on the west side of the facility the distance from noises generated on the site to the property lines of noise-receiving lands on the west side of the facility is 300 feet.

LEGEND

▬ ▬ Net Site (available for development)

ZONING DISTRICTS

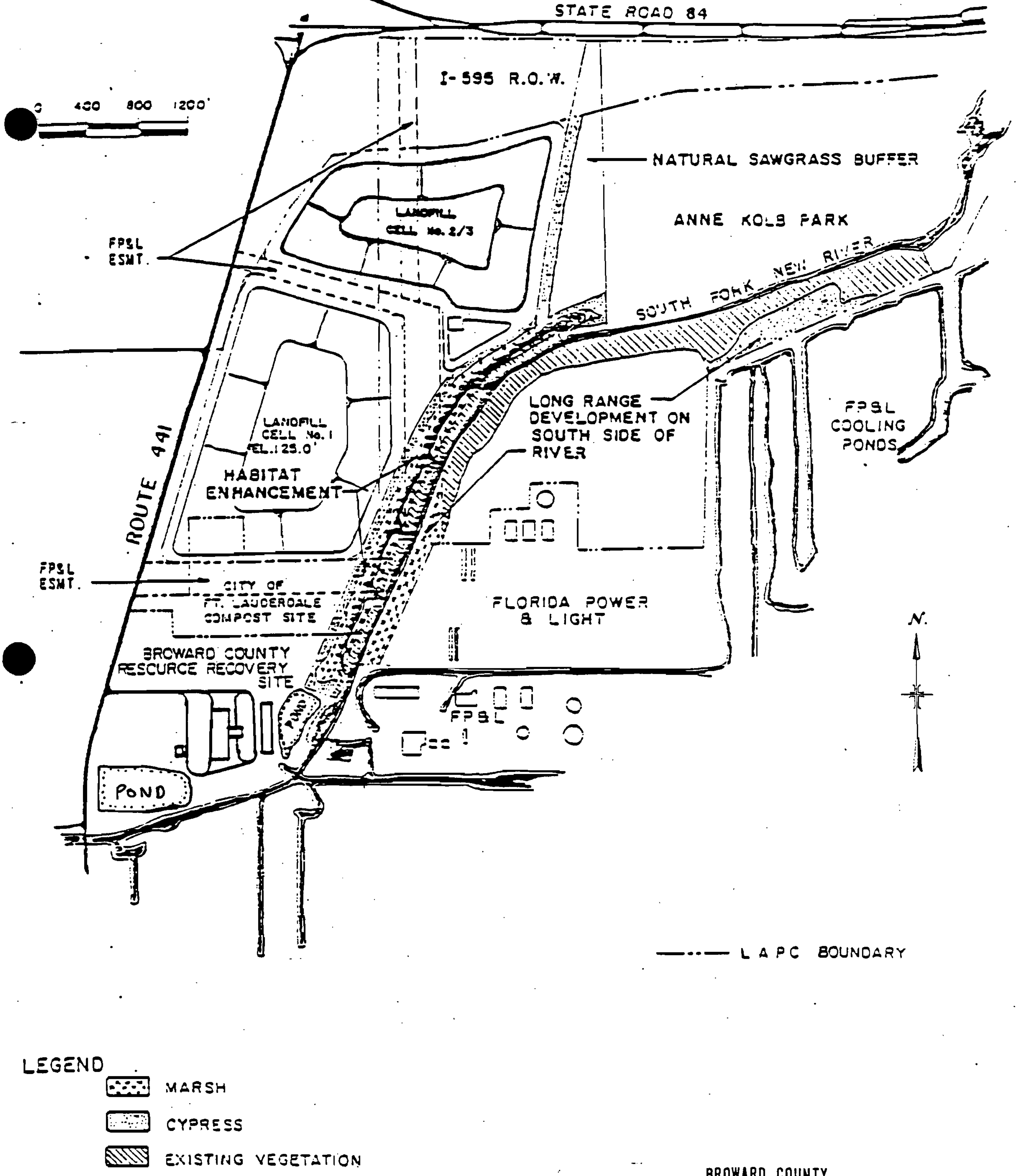
A-1	Limited Agricultural
B-2	Community Business
B-3	General Business
C-1	Commercial
M-1	Light Industrial
M-3	General Industrial
PUD	Special Use Planned Unit Development
R-1C	Single Family Residences
R-2	Single Family Duplex
R-2U	Two Family Residences
T-1	Travel Trailer Park



BROWARD COUNTY
RESOURCE RECOVERY PROJECT

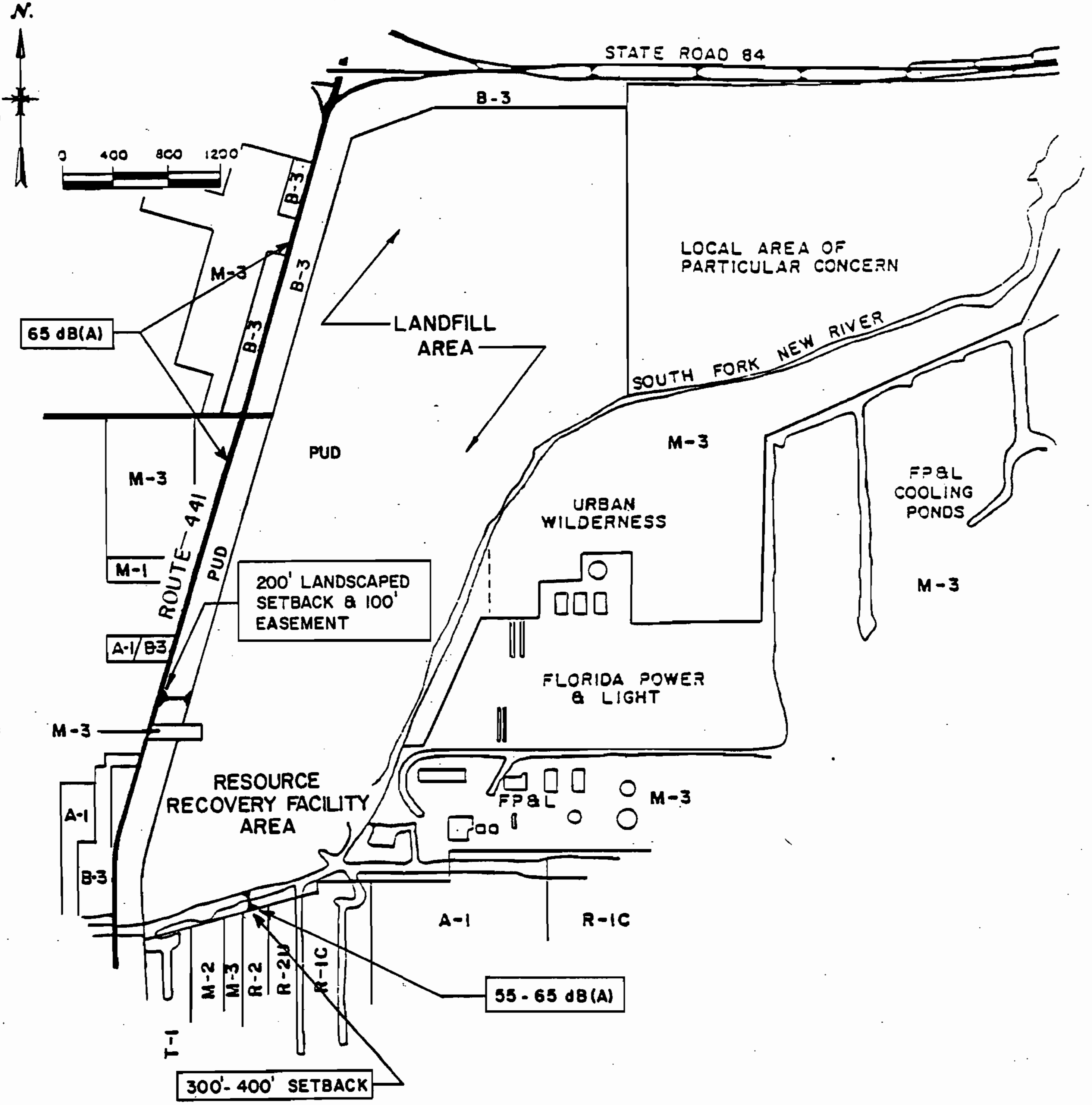
SOUTHERN SITE
ZONING
1984

FIGURE 3



BROWARD COUNTY
RESOURCE RECOVERY PROJECT
CONCEPTUAL DEVELOPMENT AND
ENVIRONMENTAL ENHANCEMENT PLAN
FOR THE ROUTE 441 SITE

FIGURE 4



A-1	LIMITED AGRICULTURAL DISTRICT
B-3	GENERAL BUSINESS DISTRICT
M-1	LIGHT INDUSTRIAL DISTRICT
M-3	GENERAL INDUSTRIAL DISTRICT
M-4	LIMITED HEAVY INDUSTRIAL DISTRICT
R-1C	SINGLE FAMILY RESIDENCES
R-2	SINGLE FAMILY DUPLEX
R-2U	TWO FAMILY RESIDENCES
T-1	TRAILER PARK DISTRICT
PUD	PLANNED UNIT DEVELOPMENT

BROWARD COUNTY
RESOURCE RECOVERY
SOUTHERN SITE ZONING
AND
PREDICTED NOISE LEVEL MAP

In the landfill (or northern) section of the southern site, as has already been discussed in the preceding section, there is the possibility that trucks, generating noise of 80 dB(A), will operate intermittently on landfill service roads immediately east of the two-hundred foot setback line. Noise from slow-moving trucks would be attenuated by 15 dB(A) to 65 dB(A) simply by virtue of the 300 foot distance.

In the resource recovery (or southern) section of the southern site, on-site noises will be generated by slow-moving refuse and residue trucks and by operation of the facility itself.

Noise from slow-moving trucks, as with landfill operations discussed above, will again be intermittent and will affect the properties west of Route 441 and the properties south of the site and across the New River Canal. On-site, intermittent noises generated by slow-moving trucks reaching the properties zoned for business and for industry on the west side of Route 441 will be similar to those truck-generated noises discussed above in connection with landfill operations.

On-site, intermittent noises generated by slow-moving trucks will also travel an estimated 300 to 400 feet to residential-zoned properties across and south of the New River Canal. At those properties, these truck noises will have been reduced by 15 to 18 dB(A), or from 80 dB(A) to 65 to 62 dB(A), respectively.

On site noise generated from plant processing operations will be either largely contained within the structure or shielded from projection to the residential properties by the location of the sources on the north side of the facility.

The steam condenser water cooling tower, if required, will be surrounded by a noise-attenuating wall/barrier with height taller than the towers themselves. In addition, attenuation of cooling tower noise will result from its location on the north side of the facility. The facility will thus be between the tower and the residential areas to the south.

For a basis of comparison, noise level readings were taken on February 24, 1984 around the periphery of the Pinellas County Refuse-to-Energy Facility in St. Petersburg. The facility was in operation and has generally comparable process technology and generally similar facility plot plans to those proposed for this Broward County project. Outdoor equipment at the Pinellas facility includes the turbine-generator, the exhaust steam condenser, most of the steam system feedwater pumps, much of the residue handling conveyor system, and large evaporative cooling towers for cooling the exhaust steam condenser water. Noise readings at the described locations at the Pinellas facility were as follows:

o	Exit truck road, 200' south of outside steam turbine/generator and condenser	65 dB(A)
o	Truck road 200' west of enclosed and elevated tipping floor and on the opposite side from the cooling tower	50 dB(A)
o	City street, 500' to east of plant (large 3-cell, evaporative-type water cooling towers between plant and street)	60 dB(A)
o	Near truck weighing station, 500' north of plant (high earth berm between station and plant)	50 dB(A)

Based on noise levels measured during operation of the Pinellas County facility, the noises will be well under the applicable limitations set forth in Section 27-7.04 of the noise code (discussed in Section 2.0) at the property lines of the residential districts.

2.0 NOISE REGULATIONS

2.1 Overview

The Broward County Environmental Quality Control Board (EQCB) requires through the County Code of Regulations, Chapter 27-7, "that any person causing a device, process, or service to be operated or constructed which may be a source of noise pollution, must submit to this office appropriate plans and applications for approval prior to construction, installation, or operation." Appendix A contains applicable excerpts from Chapter 27-7.

This application is for a permit to construct a resource recovery facility and its associated residue/unprocessable waste landfill. Noises generated during normal daily operations at the facility and landfill are described and compared to regulations.

2.2 Allowable Noise Levels

Section 27-7 of the Broward County Code of Regulations govern allowable noise levels and noise permitting in Broward County. Specifically, the regulations set standards for noises which are measured according to regulation at the boundary line of the property of the noise source, as described in Section 27-7.041:

> "No person shall operate or cause to be operated any source of sound arising from those activities set forth...in such manner as to create a sound level which exceeds the limits...for the receiving land use district...for more than 50% of any measurement period which shall not be less than 10 minutes, when measured at or within the boundary of a property within the receiving land use district and as a result of a source of sound being located on some other property."

Specifically applicable activities which are regulated, and the hours for which regulation are applicable, are as follows:

Activity	Time Period
Construction and demolition	7 p.m. to 7 a.m.
Engines, generators, pumps, motors, and other machinery	all times

Specifically exempted from noise control provisions are the following activities, among others:

- Motor vehicles operating on a public right-of-way.
- Any noise generated by the movement of aircraft in accordance with or pursuant to applicable federal laws or regulations.
- Any noise generated by the operation of engines, generators, pumps, construction tools, or other equipment for emergency use.

Specific levels are set depending on the zoning designation of the property adjacent to the site from where noise is generated. These "Sound Level Limits", not accounting for "not to exceed" allowments, discussed below, are as follows:

SOUND LEVELS BY RECEIVING LAND USE

Receiving Land Use District	Time	Sound Level Limit (dBA)
*Residential	At all times	55
Recreational or Institutional	7 A.M. - 10 P.M.	60
Recreational or Institutional	10 P.M. - 7 A.M.	55
*Commercial or Business	At all times	65
*Manufacturing, Industrial, or Agricultural	At all times	70

*These zoning designations occur adjacent to the southern resource recovery/landfill site.

The regulations further state that maximum sound levels, as measured according to regulations, shall not exceed the "Sound Level Limit" as listed above by:

1. 10 dBA from 7 a.m. to 10 p.m. for all receiving land use districts except manufacturing, industrial, or agricultural;

2. 5 dBA from 10 p.m. to 7 a.m. for all receiving land use districts except manufacturing, industrial, or agricultural; and,

3. 10 dBA at all times in a manufacturing, industrial or agricultural receiving land use district.

3.0 REGULATORY COMPLIANCE

3.1 Predicted Noise Levels and Standards

Table 3 is a summary of the projected noise levels at property lines as compared to the standards set forth in the Broward County Code of Regulations, Chapter 27-7.

As can be seen from this table, it is projected that all noises generated on-site are attenuated adequately to ensure regulation compliance at all property lines at the perimeter of the site. Noise impacts with respect to various zoning classifications are projected to be in compliance with standards based on these zoning classifications. Figure 4 is a map which illustrates the locations of these areas.

TABLE 3

PROJECTED NOISE IMPACTS (dB(A))

Noise Source	Noise Level 50' from Source	Distance to Closest Property Line	Zoning Classification Impacted	Noise Attenuation[1]	Noise Level at Property Line[2]	Noise Standard[3]
Trucks at Landfill	80	300', west	industrial	15	65	70
Trucks at Facility	80	300-400', south	industrial, agricultural	15	65	70(+10)
Steam Condenser at Facility[5]	-	300-400', south	residential	-	approx. 55 dB	55(+10)[4]

1. Attenuation is by distance (see Section 1.4) for trucks. For steam condenser, attenuation is by distance and a noise attenuating barrier.
2. Noise level at source - noise attenuation.
3. Sound Level Limit (+ allowable increment), from Chapter 27-7 of the Broward County Code of Regulations (see Section 2.2).
4. Standards require that levels measured at residential areas cannot exceed 55 dB(A) for more than 50% of any measurement period. It is predicted that trucks noises above 55 dB(A) will not occur for more than 50% of any measurement period. Further, regulations state that a sound level limit of 65 dB(A) may not be exceeded during the hours of 7 a.m. to 10 p.m.
5. Figures extrapolated from Pinellas County facility data. Noise reading at Pinellas County, 200 feet from the noise source, was 65 dB(A). Attenuation is expected to be achieved by distance and by noise attenuating barriers and surrounding structures.

Attenuation is in most cases achieved by virtue of the distance between the noise source and the point of measurement along the property lines of the site. In the case of the noise generated by the steam condenser water cooling tower, additional attenuation will be achieved through the utilization of noise attenuation walls, as well as of the facility building which will be located between the tower and the property line.

3.2 Action Requested

It can be seen from this permit application that predicted noise generation levels resulting from the operation of the proposed resource recovery facility and associated residue/unprocessable waste landfill in Southern Broward County will be in compliance with applicable regulatory standards. It is therefore requested that the Broward County Environmental Quality Control Board grant approval of this application to Construct a Noise Pollution Source for the referenced facilities.

4.0 SUMMARY

The following points present a summary of this Noise Technical Analysis:

- Ambient noise levels at the southern site and at an operating resource recovery facility in Pinellas County were measured and recorded. From this data and known generation levels and noise attenuation behavior, predictions of noise levels at property boundaries are calculated.
- Allowable noise levels, as established by the Broward County Environmental Quality Control Board in Chapter 27-7 of the County Code of Regulations are presented. These regulations include standards which differ according to the nature of the noise source, the time of day, and the zoning classification of the impacted area.
- Finally, noise standards are compared to projected generation levels. Projected levels comply with all regulations, including those specific to time of day, zoning classification, and the nature of the noise source. The noise generated through the daily operation of the southern resource recovery facility and its associated residue/unprocessable waste landfill is not expected to threaten the public health, welfare, safety or the quality of life of Broward County citizens.

Appendix 10.11

APPENDIX A

TECHNICAL SPECIFICATIONS

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TECHNICAL SPECIFICATIONS

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APPENDIX A
TECHNICAL SPECIFICATIONS
SECTION 1 - RESOURCE RECOVERY FACILITIES

1.1 Introduction

The intent of these technical specifications is to set minimum guidelines and functional design requirements to insure comparable proposals of uniform quality and to establish specific standards for the construction and operation of the facilities. In no instance is there any intent to limit the Proposer from adding to these minimum requirements and guidelines, or to unfavorably affect the use of proprietary systems and subsystems developed by manufacturer-suppliers through their own research and development efforts.

If a Proposer desires a change in the functional design requirements described herein, the Proposer shall submit identification of the change by utilizing Form 2.2 contained in the RFP. As discussed in Section 1 of the RFP, these facilities shall include two resource recovery facilities and two final Residue/Unprocessable Waste disposal landfills. In this specification, unless the context otherwise requires, words imparting the singular include the plural and vice versa. Thus, these technical specifications will apply to each facility.

The Contractor shall provide the necessary facilities to dispose fully of all the municipal solid waste (MSW) delivered to the facilities.

The Contractor shall not receive or dispose of pathogenic or hazardous industrial wastes.

Each resource recovery facility shall process all processable waste delivered to the facilities as received and shall obtain the following outputs:

- Electrical energy
- Recovered materials (optional)
- Ash residue

These technical specifications are based on a mass-burn system technology wherein the waste shall be burned continually in furnace-boilers under controlled conditions of air pressure and temperature. Steam, produced in the boilers, shall be passed through a turbine-generator set to generate electricity. The residue and siftings shall be cooled either by spray or quench, and eventually landfilled if no reuse can be found for them. Gas stream particulates and fly ash removed by electrostatic precipitators before the gases are discharged into the atmosphere may be conveyed to a common residue removal system, along with boiler ash or the fly ash and boiler ash may be removed by separate systems from the plant.

The Contractor shall supply, maintain and operate all necessary process equipment and machinery. All equipment shall be arranged in such a way as to insure safety, good housekeeping, accessibility, and ease of replacement and/or maintenance of the equipment. All equipment and machinery shall be new and of the latest proven design. The process design shall include adequate redundancy to meet the required availability and process requirements. In addition, the facilities shall be designed to accommodate future expansions that may be necessitated as a result of increased waste generation.

In accordance with Section 4 of this RFP, a minimum of three distinct and independent process lines shall be provided at the southern resource recovery facilities, and a minimum of two distinct and independent process lines shall be provided at the northern resource recovery facility. Each process line shall, as a minimum, include the following:

- A refuse-fired mass-burning furnace/boiler (steam generator) with appurtenances
- Residue conveyors with appurtenances

- An electrostatic precipitator with appurtenances

- An induced draft fan and related duct work

- Instrumentation

Common elements to each resource recovery facility shall include, but not necessarily be limited to:

- MSW/residue weighing system
- Enclosed tipping floor
- Refuse storage pit
- Refuse charging cranes and grapples
- Collecting residue conveyors
- Ferrous removal systems (optional)
- Condensers
- Water treatment equipment
- Steam extraction headers and controls
- Turbine/generator set or sets
- Stacks
- Centralized process control system

1.2 General Requirements

1.2.1 Civil Engineering

The design of each facility shall take into account the existing site conditions with respect to soil conditions, site clearing and drainage. The Proposer shall be responsible for any site preparation including soil stabilization.

Site grading shall meet the requirements for necessary flood protection and be compatible with the general topography of the adjacent properties.

1.2.2 Image

It is important to the County that, because of the anticipated physical size and the activities that take place in and around these facilities, utmost care be paid to minimize any possible adverse impact of the presence of each facility to the public. In this regard, a sensitive and careful urban planning effort is required in the siting and architectural design.

The buildings and grounds of each facility should be designed to project a coherent image of each facility's function and value to the community. Exterior building materials and fenestration shall project an image of quality and functionalism. This architectural image should be contemporary in tone, visually low-key on the exterior, and embody current design for industrial buildings. Each facility should be perceived by the public as a resource and energy recovery industrial building and not as an incinerator or refuse dump. A GOOD NEIGHBOR RELATIONSHIP IS MANDATORY FOR EACH FACILITY AND THE SURROUNDING COMMUNITY.

The visual quality of each facility's stack design with regard to siting, material, and color options shall be considered.

1.2.3 System Availability

The facilities shall be designed using a modular approach with sufficient equipment redundancy to avoid shutdowns or outages. Each facility shall be designed to accept those quantities delivered by the County and the contract municipalities in accordance with their normal collection and delivery practices. The facilities shall be designed to process 1,095,000 tons of Processable Waste per year, 21,000 tons per week, 3,000 tpd, with allowances made for scheduled and unscheduled downtime.

The system designs shall provide for continuous performance.

Guaranteed availability shall be based on a proposed energy output for each ton of input at varying MSW heating values. The extent to which the guaranteed availability changes with changes in the heating value of the wastes shall also be guaranteed.

1.2.4 General Facility Process Design Requirements

The design of each facility shall incorporate the following requirements:

- Each facility shall be designed so that all the Processable Waste received will be processed in a highly reliable manner. The Proposer will clearly state and demonstrate the long-term reliability and availability of the systems proposed.

- Each Processable Waste storage pit shall be large enough to hold a minimum of four times the daily Nampelate Capacity of the facility based on an in-pit density of 500 lbs per cubic yard and without exceeding the elevation of the tipping floor. Minimum volumes for the storage pits shall be 24,000 cubic yards at the northern facility and 32,000 cubic yards at the southern facility.

- Each vehicle shall be weighed upon entering the site to determine the net payload of the MSW delivered.

- On-site MSW truck traffic flow shall be designed to minimize conflicts and to allow a maximum on-site time of ten minutes for any vehicle, even during peak traffic periods.

- Sufficient unloading bays shall be provided to meet the above stated time criteria in regard to the unloading of Processable Waste in a totally enclosed tipping area.

- Visitor accommodations shall be provided along with the appropriate walkways, galleries, conference rooms, and control room access.

- The Proposer shall incorporate the following checklist in the design of each facility:
  - Weighing station - automated, with one standby scale
  - No truck queuing on the ramps or public roadways
  - Cranes - minimum of two each at one hundred percent of daily facility capacity, or three each at fifty percent capacity. The crane grapples shall have the capabilities to transfer the Processable Waste quantities at these crane capacities from the storage pit to the charging hoppers.
  - Manual overrides for all systems and equipment with automatic controls
  - Maximum furnace sizes - 750 tons/day
  - Turbine-generator units
  - Air Pollution Control - Electrostatic Precipitators, one per process line

- Stack(s) height - at each facility a maximum of 200 feet above final grade elevation
- Residue removal system - each one hundred percent nominal capacity conveyor systems
- Utility interconnection - as per the requirements of the Florida Power and Light Company (FP&L)
- Fire fighting system

1.2.5 Applicable Codes and Standards

The design and construction of all structures, along with all the equipment, component parts, and ancillaries, shall conform with all governmental and industry codes and standards. Without limiting the foregoing, The South Florida Building Code shall be followed, including requirements for:

- construction classifications,
- fire restrictive construction,
- fire protection systems,
- elevators.

In addition, the latest issues of the following codes and standards for construction and operation of each facility, shall be incorporated in the design.

- American Association of State Highway and Transportation Officials (AASHTO)
- American Institute of Steel Construction (AISC) Specifications
- American Welding Society Code
- Applicable codes and standards of the American National Standards Institute (ANSI)
- American National Standards Building Code Requirements for Minimum Loads in Buildings and Other Structures (ANSI A58.1)
- Instrument Society of America (ISA)
- Applicable codes and standards of the American Society for Testing and Materials (ASTM)
- Air Mixing and Conditioning Association (AMC)
- ASHRAE Handbook and Standards

- Tubular Exchange Manufacturers Association (TEMA)
- American Society of Mechanical Engineers (ASME) - Boiler and Pressure Vessel Code
- Hydraulic Institute Code (HIC)
- Heat Exchanger Institute (HEI)
- American Concrete Institute (ACI)
- Steel Structures Painting Council (SSPC)
- All Standards Promulgated by the U.S. Secretary of Labor under Occupational Safety and Health Administration (OSHA)
- Institute of Electrical and Electronic Engineers (IEEE)
- National Electrical Code (NEC)
- National Electrical Manufacturers Association (NEMA)
- National Fire Protection Association Codes (NFPA)
- National Board of Fire Underwriting (NBFU)

In the event that any of the above codes or standards conflict with one another, the most stringent requirement shall be applied.

1.2.6 Utilities

General: It is the responsibility of the Proposer to inform the County of the quantities of all utilities required by each proposed facility. The Proposer shall indicate in the proposal if there is an insufficiency in utilities supplying the sites. Off-site costs associated with providing utilities capacity (exclusive of cooling water requirements) in excess of those immediately available shall be treated as "developmental costs" to be included in the Project financing.

The design and installation of all utility connections shall be in accordance with the requirements of the utility suppliers and will be considered as part of the design of each facility.

Water: The requirements of the South Florida Water Management District shall be met, including those for permits.

It is the Proposer's responsibility to include in the proposal, details on the treatment of the water as may be required for plant operations and any pretreatment requirements for industrial wastewater. In addition, the Proposer shall include stormwater drainage plans for the resource recovery facilities and Residue/Unprocessable Waste landfills.

The water quantities and pressures required for plant processing and other purposes, including fire protection, shall be included in the Proposal. If the County cannot provide the quantities and pressures required, auxiliary sources for obtaining same shall be included in the Proposal.

The Proposer shall consider for process water the use of non-potable well water, the recycling of plant wastewater, and the potential use of plant effluent. The Proposal shall include a complete description and estimates for each auxiliary source. Compliance with all applicable codes is mandatory.

Sanitary Sewer: The Proposer shall submit in the Proposal, design data on his projected water discharges, including quantities and qualities of discharge and pretreatment, if required, i.e., characteristics as defined by the rules of the County and/or the host municipality user charge/industrial cost recovery systems. The Proposal shall also include methods to handle discharge if the present systems cannot accept it. Applicable codes and requirements of the State and the County shall be complied with.

Storm Drainage: Storm drainage for the sites shall be developed to conform to all requirements of the South Florida Water Management District (SFWMD). All plans shall be reviewed with the County for conformance with code and other requirements of the SFWMD. The Proposer shall submit calculations showing the method for determining runoffs. On site retention lakes will be required for storm drainage control. As part of the County's permit application procedure, preliminary storm drainage plans have been developed and submitted to the SFWMD.

Storm drainage plans shall be reviewed with the County for conformance with code and other requirements of the SFWMD.

<u>Electrical Power</u>: Florida Power & Light (FP&L) will bring transmission power to the facility substations. Power requirements and the suggested operating compatibility for the electrical system for each facility during the construction, start-up and operation phases, and for backup, shall be provided in the Proposal. The electrical system includes the plant distribution system, the type of metering, the interconnection systems with FP&L and FP&L protection costs within the interconnection systems. The Proposer shall provide electrical power specifications to the County and shall make all arrangements for electrical service during construction and start-up through FP&L.

For utility interconnection, the design and installation shall be in accordance with the requirements and standards imposed by FP&L and shall be part of each facility. FP&L shall tie-in to electrical substations to be located within each facility site.

The mode of electrical energy distribution shall meet with the following:

- Each turbo-generator and associated power generation equipment shall have its own bus which is to be at the same voltage level as the generator. Synchronizing and protective relays shall be provided on each generator breaker.
- Interconnect transformers shall each be sized for the full output of the plant.
- Complete indoor relay and control switchboards shall be provided for each facility's electric systems.

The distribution systems at each facility shall have 4.16 KV and 400 volt systems with switchgear and related accessories housed in the processing section of each of the facilities.

The electrical output of the turbine-generator sets shall operate within the interconnection system established by FP&L. The turbine-generator sets shall be capable of operating in the full condensing mode, at maximum steam flow, even on the hottest day of the year, and still provide an efficient and adequate quantity of electrical energy.

In addition, payment to FP&L shall be required for interconnection and protection costs associated with the northern and southern facility electrical interconnections, and for the following additional costs:

- Monthly telephone company charge for FP&L dispatcher communication channel, which has been estimated by FP&L at $175 per month at each site.
- Maintenance and operation fee to FP&L for interconnections facilities.
- Metering costs.
- Suitable arrangements for termination of FP&L lines. The service points may be adjusted if desirable to provide suitable line terminations.
- Suitable right-of-ways and easements both on and off the sites for the transmission lines. Thirty-six foot minimum width, accessible easements are required. The right-of-ways must be cleared and finished to adequate grade. Costs of fees and permits, if applicable, shall also be paid.

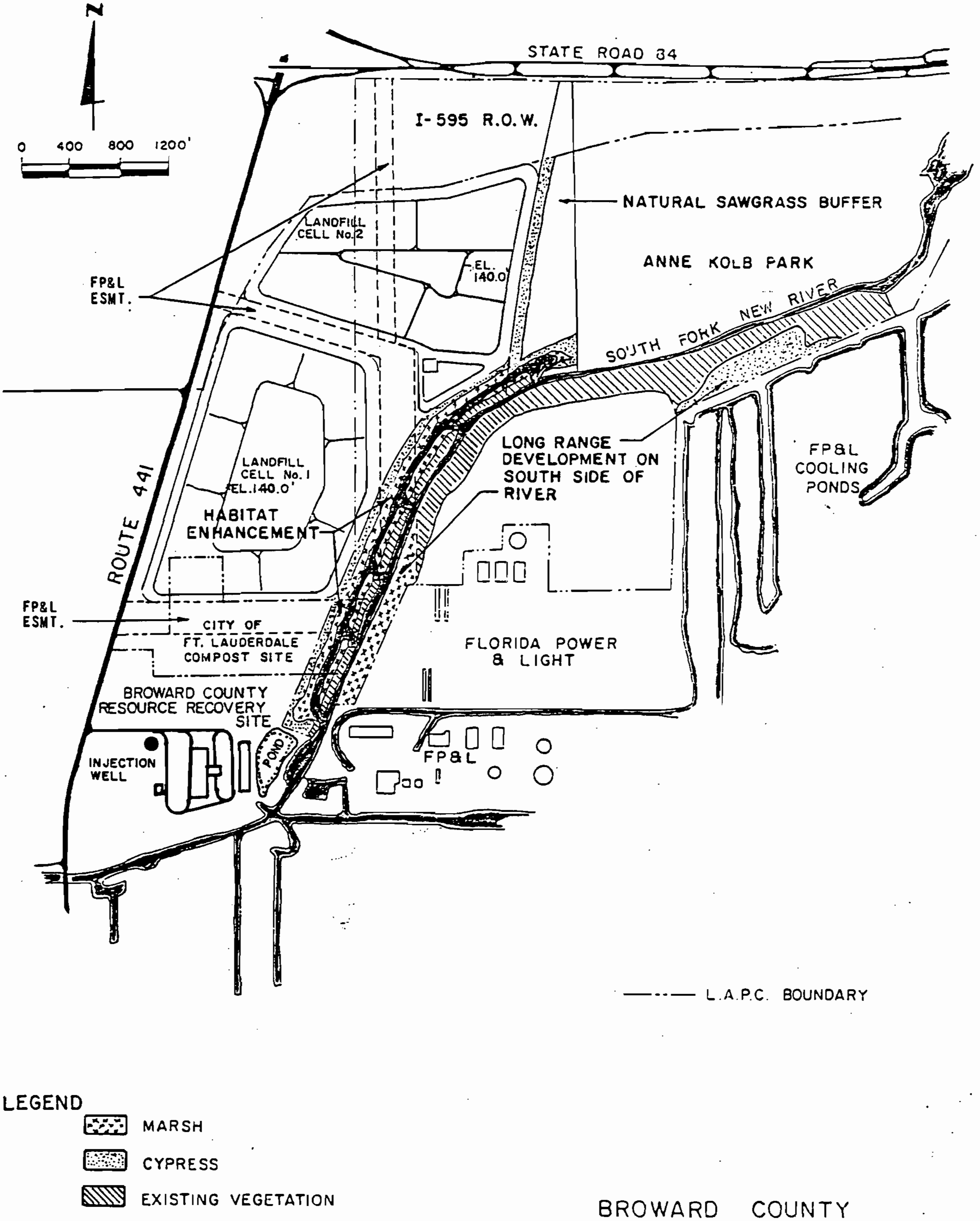
1.2.7 Site Utilities

This subsection provides information on available utility service for the Route 441 and Copans Road Sites. However, it is the responsibility of the Proposer to verify and supplement this information where necessary.

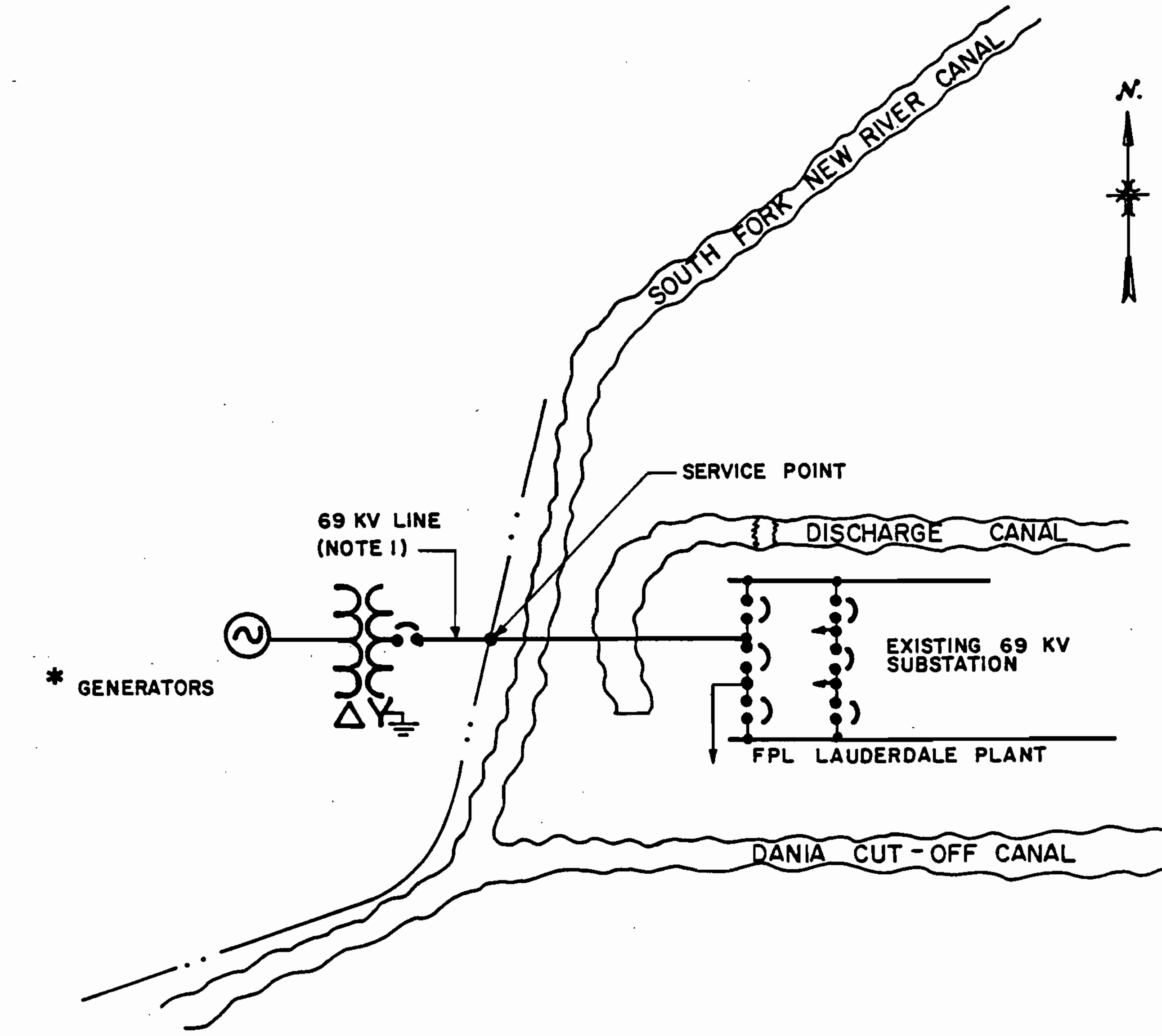
Route 441 Site

Figure 1A illustrates the known utility locations adjacent to the Route 441 site. The electrical interconnection proposed by FP&L is shown in Figure 2A.

figure 1A



BROWARD COUNTY
RESOURCE RECOVERY
CONCEPTUAL DEVELOPMENT AND
ENVIRONMENTAL ENHANCEMENT PLAN
FOR THE ROUTE 441 SITE



* GROSS OUTPUT MAY BE SUPPLIED BY TWO GENERATORS

NOTE 1

PROVIDE FOR FUTURE CONVERSION FROM 69 TO 138 KV

BROWARD COUNTY
RESOURCE RECOVERY

ELECTRICAL INTERCONNECTION SCHEMATIC
ROUTE 441 SITE

Electric Service: For the southern facility, FP&L indicates that a 69 KV transmission line will be extended westwardly across the South Fork New River Canal from FP&L's Lauderdale Power Plant Substation to the southern site's substation. The routing of this line will require coordination in the development of the resource recovery plant. The facilities at the southern sites should be designed to facilitate future conversion of the 69 KV service voltage to 138 KV.

Florida Power and Light has developed an interconnection cost estimate, including modifications to offsite substations and transmission lines, for the southern site. This estimate, based on the above assumptions is $300,000 which does not include the cost of the transformer, circuit breaker or protective equipment installed at the site.

The above cost, in current dollars, should be regarded as a budget estimate to provide feasibility guidance. Since the Project will pay on the basis of actual cost including appropriate overheads, rather than estimated cost, the estimates must be reviewed when specific designs become available.

Water Service: Water requirements can potentially be provided by Broward County or the City of Fort Lauderdale. Broward County has an existing 12-inch diameter water main, which runs east-west along Griffin Road south of the project site. An 8-inch line extends north from that main to a point adjacent to the resource recovery facility site. Water quality data for the County water plant that would provide service to the southern site is provided in Table A-1. Preliminary information from the County indicates that approximately 100 gpm of water from the County water system may be available to this site.

Service by the City of Fort Lauderdale would require a main extension from the New River Canal, Route 441

TABLE A-1
1982 AVERAGE ANNUAL WATER QUALITY VALUES FOR THE BROWARD COUNTY SYSTEM 3-A PLANT

Analytical Results	Raw Water	Finished Water
Water pH at the Plant	7.25 units	8.75 units
Water pH at the Field	-	8.50 units
Water Color at the Plant	63 CU	12.0 CU
Water Color at the Field	-	12.8 CU
Water Odor No. Dilutions	3 DIL	-
Water Turbidity	-	0.41 BTU
Water Free Carbon Dioxide	21 mg/l	0 mg/l
Calcium Hardness as $CaCO_3$	209 mg/l	63 mg/l
Magnesium Hardness as $CaCo_3$	18 mg/l	14 mg/l
Total Hardness as $CaCO_3$	227 mg/l	77 mg/l
Total Mo. Alk. as $CaCO_3$	198 mg/l	26 mgl
Non Carbonate Hardness as $CaCO_3$	29 mg/l	51 mg/l
Calcium as Ca^{+2}	83.6 mg/l	25 mg/l
Magnesium as MG^{+2}	4.4 mg/l	3.4 mg/l
Iron as Fe^{+2}	1.67 mg/l	0.03 mg/l
Sodium as Na^{+1}	23.2 mg/l	23.8 mg/l
Bicarbonate as HCO_3^{-1}	242 mg/l	31.7 mg/l
Chloride as Cl^{-1}	35 mg/l	52.4 mg/l
Sulfate as SO_4^{+2}	17.0 mg/l	18.0 mg/l
Fluoride as F^{-1}	0.19 mg/l	0.88 mg/l
Total Dissolved Solids	408 mg/l	173 mg/l
Total Res. Chlorine	-	2.9 mg/l
Total Free Chlorine	-	2.5 mg/l
Total Comb Chlorine	-	0.4 mg/l
Saturation Index	+0.00	+0.14 mg/l

intersection south to the site. This extension will necessitate crossing Route 84 and the proposed I-595 interchange. Preliminary information from the City of Fort Lauderdale indicates that approximately 100 gpm of water may be available from the City's Peele Water Plant. Water quality data for this plant is provided in Table A-2.

Sewer Service: As with water, sewer service can potentially be provided by either Broward County or the City of Fort Lauderdale.

The Broward County system consists of small submersible pump stations discharging through a 6-inch diameter force main located on Griffin Road. The possibility that increased flow through the Broward County system will significantly affect hydraulic conditions must be addressed.

The City of Fort Lauderdale operates pumping station D-54 on S.W. 20th Street to the north of the project site. This is a large station which would probably not be affected by increased flow from the resource recovery facility. However, the piping required to meet the City system must pass across Route 84 and proposed I-595.

Copans Road Site

Figure A-3 illustrates the location of known utilities, adjacent to the Copans Road Site. The electrical tie-in proposed by FP&L is shown in Figure A-4.

Electric Service: For the northern facility, FP&L indicates that a 138 KV overhead transmission line will be brought to the eastern side of the site. This pole line will enter the northern site at approximately the northeast corner and extend southward along the east property line to the northern site's substation.

Based on the above assumptions, Florida Power and Light has estimated the interconnection costs for this site, including modifications to offsite substations and transmission lines at $800,000. This estimate does not include the

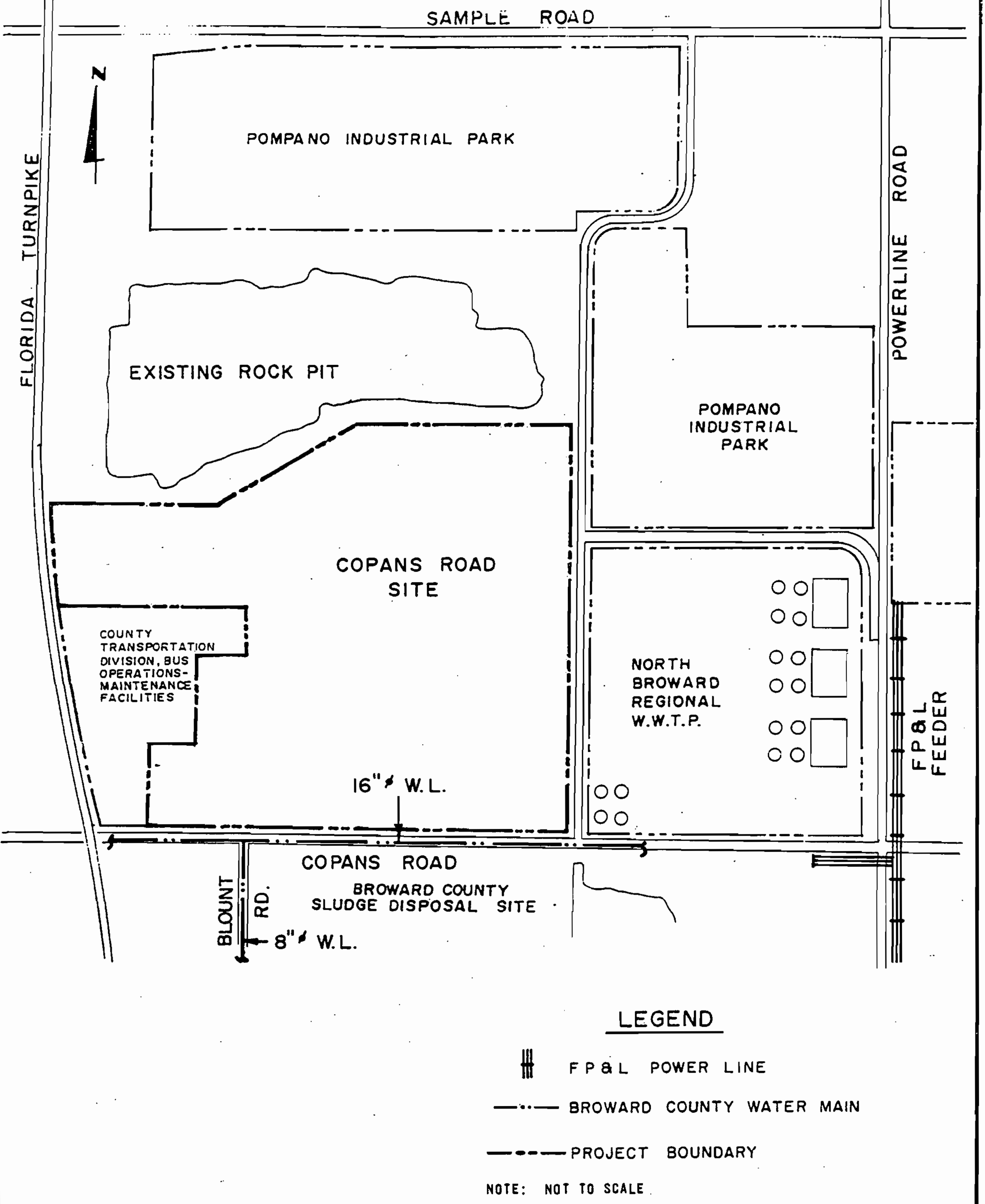
TABLE A-2

1982 AVERAGE ANNUAL WATER QUALITY VALUES FOR THE CITY OF FORT LAUDERDALE'S

WALTER E. PEELE PLANT

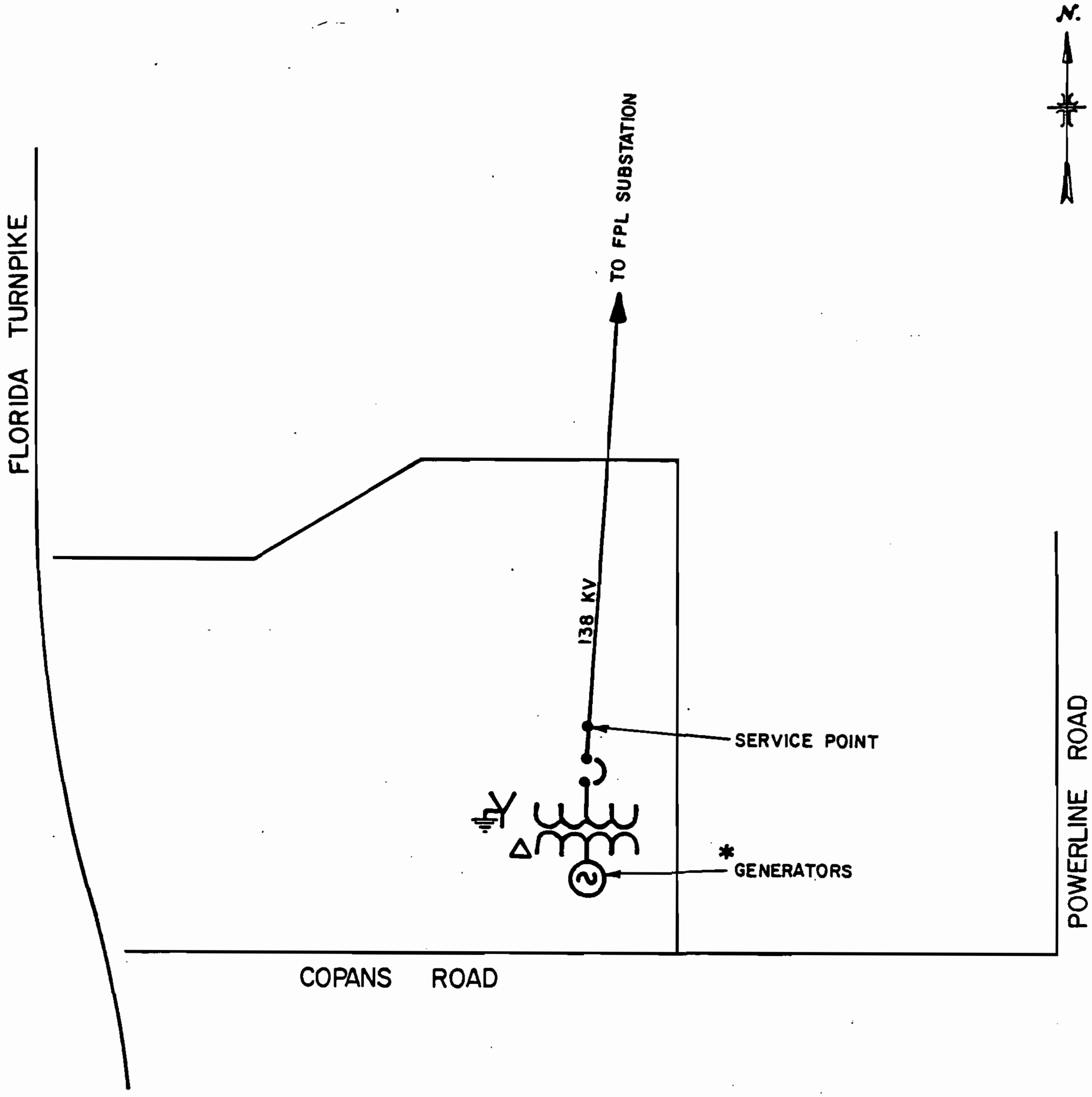
Analytical Results	Raw Water	Finished Water
Water, pH	6.9 units	9.1 units
Water Color	3.65 CU	5.25 CU
Turbidity, NTUO	-	0.36
P Alkalinity	-	8.5 mg/l
M Alkalinity	-	39.7 mg/l
Total Mo. Alkalinity	224 mg/l	-
Calcium hardness as $CaCO_3$	254 mg/l	81 mg/l
Total Hardness as $CaCO_3$	165 mg/l	90.5 mg/l
CO_2 Calcium	54 mg/l	-
Iron as FE	1.85 mg/l	0.11 mg/l
Chlorides as Cl^{-1}	42 mg/l	53.7 mg/l
Residual Chlorine	-	2.5/3.4

FIGURE A-3



UTILITY LOCATIONS ADJACENT TO THE COPANS ROAD SITE

BROWARD COUNTY
RESOURCE RECOVERY



* GROSS OUTPUT MAY BE SUPPLIED BY TWO GENERATORS.

BROWARD COUNTY
RESOURCE RECOVERY

ELECTRICAL INTERCONNECTION SCHEMATIC
COPANS ROAD SITE

cost of the transformer, circuit breaker, or protective equipment necessary to be installed at the facility.

The Contractor would be responsible for installation and operation of the step down transformers, interfacing circuit breakers and protective equipment.

The preceding cost, in mid 1983 dollars, should be regarded as a budget estimate to provide feasibility guidance. Since the Project will pay on the basis of actual cost including appropriate overheads, rather than estimated cost, the estimates must be reviewed when specific designs become available.

Water Service: Water may be provided from the Broward County water distribution system. Preliminary discussions with the County indicate that approximately 100 gpm of water may be available from the County water system to this site. Water quality data for the County water plant that would provide to the northern site is provided in Table A-3.

Sewer Service: The Copans Road site is located immediately west of the North District Regional Wastewater Treatment Plant which can provide sewer service to the resource recovery facility. Broward County owns and operates this plant.

TABLE A-3
1982 AVERAGE ANNUAL WATER QUALITY VALUES FOR THE BROWARD COUNTY SYSTEM 1-A PLANT

Analytical Results	Raw Water	Finished Water
Water pH at the Plant	7.2 units	8.9 units
Water pH at the Field	-	8.6 units
Water Color at the Plant	82 CU	10.75 CU
Water Color at the Field	-	11.5 CU
Water Odor No. Dilutions	3.0 DIL	-
Water Turbidity	-	0.40 BTU
Water Free Carbon Dioxide	27 mg/l	0
Calcium Hardness as $CaCO_3$	235 mg/l	70 mg/l
Magnesium Hardness as $CaCo_3$	18 mg/l	9 mg/l
Total Hardness as $CaCO_3$	253 mg/l	79 mg/l
Total Mo. Alkalinity as $CaCO_3$	227 mg/l	29 mg/l
Non Carbonate Hardness as $CaCO_3$	26 mg/l	50 mg/l
Calcium as Ca^{+2}	94 mg/l	28 mg/l
Magnesium as MG^{+2}	4.38 mg/l	2.2 mg/l
Iron as Fe^{+2}	1.42 mg/l	0.03 mg/l
Sodium as Na^{+1}	32.6 mg/l	32.8 mg/l
Bicarbonate as HCO_3^{-1}	277 mg/l	35.4 mg/l
Chloride as Cl^{-1}	57 mg/l	82.0 mg/l
Sulfate as SO_4^{+2}	14 mg/l	14.0 mg/l
Fluoride as F^{-1}	0.14 mg/l	0.85 mg/l
Total Dissolved Solids	406 mg/l	275 mg/l
Total Res. Chlorine	-	4.1 mg/l
Total Free Chlorine	-	3.3 mg/l
Total Comb Chlorine	-	0.8 mg/l
Saturation Index	+0.06	+0.37 mg/l

1.3 Site Work

1.3.1 Subsurface Investigation

Data and information pertaining to the subsurface conditions at the southern site are provided in Appendix E of this RFP.

This data will be supplied for informational purposes only. The Contractor must assure itself that subsurface conditions are compatible with its facilities.

1.3.2 Survey

The Contractor shall furnish all labor, materials, tools, equipment, to perform all work and services necessary for or incidental to the performance and completion of survey work necessary for the construction of site work, buildings, new utilities, and other new facilities and establish and maintain bench marks, make measurements to verify location of completed construction, and survey alignment to existing property boundaries.

The following conditions shall be followed in making the above described survey:

- A survey shall be made to establish the property site lines.
- Copies of all the County's survey information will be made available at Contractor's expense.
- The Contractor shall not disturb existing benchmarks or property line monuments. Work necessary to replace stakes and monuments as directed by the County shall be at the Contractor's expense.

1.3.3 Clearing, Grubbing and Site Preparation

Underground Void Areas: Such as tanks, cisterns, tunnels, or the like shall be removed or filled according to all pertinent codes and regulations.

Shoring: All temporary shoring required to support existing work, and adjacent areas and work shall be furnished and installed to prevent settlement or other damage to surrounding areas and structures and shall be provided with adequate means to compensate for any settlement in the shoring supports.

Debris: All materials removed shall become the property of the Contractor and shall be removed from the premises and disposed of by the Contractor.

Maintenance: All access roadways used by the Contractor shall be maintained in serviceable condition. The Contractor shall keep the surfaces of these roadways free from mounds, depressions and obstructions which might present a hazard or annoyance to traffic.

Signs, Signals and Barricades: All signs, signals and barricades shall be provided by the Contractor and shall meet or exceed all OSHA regulations for accident prevention.

Dust Control: The Contractor shall be responsible for all dust control at the site. The Contractor shall prevent the spread of dust during his operations. Moistening all surfaces with water or applying calcium chloride shall be used to prevent dust from becoming a nuisance to the public and neighbors. Contractor shall furnish all labor and equipment necessary for dust control including but not limited to tank trucks, hoses, calcium chloride spreaders, etc.

Burning: On-site burning shall not permitted.

Vermin and Rodent Control: During the course of construction and operation, a constant control of vermin and rodents shall be maintained by the Contractor. If necessary, the Contractor shall employ the services of a professional exterminator.

Explosives: The use of explosives shall at all times be in conformance with the conditions set forth in Section 3.5 of the RFP.

Disconnection of Utilities: Before starting site operations, the Contractor shall disconnect or arrange for the disconnection of all utility services required to be removed, performing all such work in accordance with the requirements of the utility company or agency involved.

Grubbing: The Contractor shall remove all surface rocks and all stumps, roots and other vegetation within the limits of construction.

Dewatering: The Contractor shall be responsible for performing all necessary site dewatering.

Site Drainage: The Contractor shall be responsible to install and maintain adequate drainage and prevent soil erosion at the site during construction.

1.3.4 Excavation, Filling, and Backfilling

The Contractor shall be responsible for furnishing all supervision, labor, tools, materials and equipment and performing all operations in connection with excavation of all materials regardless of character of material, and obtain fill and backfill material approved by a qualified soil engineer to produce final grade lines. All necessary arrangements for obtaining fill material and topsoil from off-site borrow areas shall be the responsibility of the Contractor.

The Contractor shall remove from the site all rubbish and debris found thereon to prepare the site for excavation.

The Contractor shall perform the required excavation of whatever materials encountered, as necessary for the construction of the Project.

Excavation for footings shall be made sufficiently wide for the installation of form work and to the depths required.

The Contractor shall prevent the foundation area from becoming unstabilized by the flow of water into the excavation or by cave-ins.

Deleterious soil not suitable for sustaining design loads must be removed entirely and controlled fill shall be placed in its stead. In areas other than under buildings unsuitable soil shall be removed to the depth required to sustain traffic loads with controlled fill placed in the area.

The Contractor's quality of work including excavation, fill, backfilling, dewatering, subgrade preparation and stabilization, shoring, drainage, for protection shall comply with soils engineer recommendations, the applicable American Society for Testing and Materials (ASTM) standards, and the Florida State Department of Transportation.

All existing utility lines, drains or other structures which are encountered or which are uncovered by excavation shall be carefully supported and protected from injury by the Contractor, and if damaged shall be restored by the Contractor at his expense to the same condition in which they were found.

Surplus excavated material over and above that required for backfilling shall be placed by the Contractor at points on the property consistent with the Contractor's landscaping plan.

Before backfilling, all excavated areas to be backfilled shall be cleared of all building rubbish, wood, lumber and dismantled from work, etc.

Backfill shall consist of suitable clean soil.

Backfill shall not be placed against walls until they have attained sufficient strength to withstand the pressure of the fill material safely.

1.3.5 Easements and Setbacks

Existing easements at the sites, such as those held by FP&L and as indicated on the site drawings in this RFP, must be observed and honored unless specific exceptions are obtained from the easement holder.

A discussion of the required buffer areas for the northern site is provided in Section 4 of the zoning ordinance for the Copans Road Site, while the Zoning and Land Use Section of the "Route 441 Site Environmental Review Form Summary and Report" dated July, 1983 contains information pertaining to setbacks and buffer areas for the southern site.

1.3.6 Site Maintenance

The Contractor shall be responsible for the maintenance of the sites. Maintenance shall include all watering, weeding, clean-up, repair of washouts, repairs to fences and all other necessary work associated with site maintenance.

The Contractor shall clean-up and remove from the site all rubbish and materials as they accumulate and shall not permit them to be scattered about the site. If the Contractor fails to attend to this clean-up promptly and satisfactorily, the County shall have the right to employ others for the work and charge the cost to the Contractor.

1.4 Architectural

1.4.1 Functional

General: The Proposer shall be responsible for developing site layouts which will meet all functional design requirements to provide for efficient operation of each facility.

Plans for each facility shall include an architectural program for all functional areas of the facility, identifying the designated use and capacity of these areas. Concepts for interior design and furnishings shall also be provided. An interior circulation plan shall be designed for efficient movement and functional operation of equipment and control by the crews of each facility. Personnel facilities should be placed in a central location to minimize walking distances.

Each complete facility, including buildings required to house process equipment and administrative functions, public areas, ancillary buildings, infrastructure such as roadways, parking areas and landscaping, shall be designed and constructed to meet all functional requirements of the Project. Each facility shall be designed and constructed of quality materials to ensure that with proper maintenance and repair the facility will remain in good condition both functionally and visually over the operating period. The selection of exterior materials should be made from the standpoint of durability, weather-resistance and easy maintenance.

The proposal shall include necessary systems for heating, ventilation, air conditioning, plumbing, lighting and power distribution, communication, fire protection, and provision for the handicapped in visitor and administrative office areas to facilitate proper operation of the process equipment and provide essential comfort for the personnel.

Each facility shall include all of the necessary equipment and their enclosures and conform to all applicable Federal, State and local codes.

Each facility shall be designed to facilitate repair and maintenance of process equipment by providing adequate space around and between equipment items.

Main Process Buildings: Each main process building shall house the refuse receiving and handling area, refuse storage area, water and waste handling systems, control room, machine shop and locker rooms. In addition, each main process building shall house an employee area, maintenance and storage areas, laboratory and the first aid center. The turbine-generator sets may be installed outdoors or may be housed within the main process building.

Exterior walls shall be durable, as well as providing noise abatement, and easily maintainable. Natural light shall be utilized throughout the main process buildings to the maximum extent possible.

Material that is easily cleaned, damage resistant against various maintenance activities, and tolerant of adverse conditions created by high humidity and equipment operation (e.g., vibration) shall be selected for the interior walls and partitions. Access stairs, ladders, platforms and elevators shall be provided in accordance with applicable sections of OSHA.

Administrative Office Spaces and Employee Areas: At each facility the administrative offices may be incorporated within the main process building or housed in a separate building. Each facility shall include suitable office space and furnishings to accommodate the facility staff and County representatives.

Conference rooms, a visitor reception area, employee locker room(s) with toilets, an employee lunch room, and toilets for staff and visitors shall also be provided at each facility. These spaces shall be furnished with all customary furniture and equipment.

Visitor Accommodations: Each facility shall provide for occasional visitors, both singly and in groups, and for on-site public educational programs.

In addition, controlled visitor viewing locations, in various process areas of each facility, shall be provided. These viewing spaces shall not be directly exposed to operating equipment to assure the safety of the public. Elevators shall be provided to facilitate visitor access and movement to all levels of each facility.

Maintenance and Storage: Each facility shall include a maintenance and machine shop and adequate storage for spare parts, equipment and rolling stock, sufficient to provide for a regular program of maintenance for all facility buildings and grounds.

The Contractor shall furnish equipment for the machine shop as part of each facility.

Each facility shall have storage spaces for all mobile vehicular equipment necessary to operate the facility and associated landfills. An enclosed vehicular garage/repair shop shall be provided at each facility.

Scale Houses: Each facility shall have a scale house as a separate building. Each shall contain, in addition to the weighing equipment, provisions for an office for the operator with the necessary furnishings and an area with toilets for truck drivers. Adequate lighting, heating, ventilating and air conditioning shall be provided. A security office shall also be located within each scale house.

Waste Sampling Areas: The enclosed tipping floors at each facility shall have provisions for use of an area on the floors for Processable Waste sampling on a selective or as-needed basis. Vehicular access shall be provided to the sampling areas. Ample space shall be provided to permit waste to be transferred from the receiving areas into a 1-cubic yard box using a small front end loader. These sampling spaces may be routinely used for other purposes and made available for test work on a coordinated basis.

Residue Handling Areas: The residue handling areas shall be enclosed to minimize the aesthetic impact of this operation, control the emission of noise and odor and to conceal the activities from the view of the public.

Laboratory: The facility shall include a fully equipped laboratory to conduct all routine testing of steam and feedwater. The detailed design of the laboratory shall be the responsibility of the Proposer.

First Aid Centers: The Proposer shall provide an area for a fully equipped First Aid Center within each facility.

Access Roads and Ramps: The access roads and/or ramps shall be designed to achieve the greatest efficiency, to minimize the use of space, to minimize the interaction of trucks with staff and visitor vehicles, and to prevent the queuing of trucks on ramps and public roadways.

Road System: The road systems shall include all roadways within the facilities. There shall be at a minimum at each facility a road from:

(1) The entrance and the exit to:
    o The weighing station
    o The main plant building
    o All auxiliary facilities

(2) The weighing station to and from:
    - The tipping area (truck ramp shall be constructed with a slope not to exceed five percent
    - The ash handling area
    - The residue/unprocessable waste landfill,

(3) The main plant building to and from:
    - All auxiliary facilities

<u>Road Geometric Design</u>: There shall be a <u>MINIMUM</u> of two twelve foot wide paved lanes for each traffic direction, one of which shall be a shoulder for breakdowns and traffic by-pass. The width of each lane shall be as a minimum the size of lane as per construction codes of the American Association of State Highway and Transportation Officials for street width for trucks. The radius or curvature of any roadway shall also be not less than the minimum curvature suggested by the same construction codes.

<u>Road Drainage</u>: Paved roads and surfaces shall be pitched so as to adequately drain all storm waters to drainage ditches or to catch basins connected to a subsurface drainage system.

<u>Site Walkways</u>: All walkways shall conform to applicable State and County requirements and the appropriate codes and standards. In addition, all walkways shall be adequately lighted, maintained and have provisions for the handicapped.

<u>Site Outdoor Lighting</u>: Sufficient outdoor lighting of roads, walkways and parking areas shall be provided to insure the safety and security of the operation of each facility, the safe movement of people and vehicles, and for security purposes.

Facility buildings shall be suitably illuminated to present the facility to the public.

Primary lighting shall be provided for the main roadways from each facility to the street gates; the gate house, if any; the refuse vehicle weighing areas (scale house); employees' parking lot; electrical substation; and pedestrian walkways. Primary lighting shall generally be of higher intensity than secondary lighting and shall utilize fixtures and post equipment of superior aesthetic and structural quality. Exterior light poles and fixtures shall be metal and shall be contemporary in design.

Secondary lighting shall cover areas where activity is more intermittent and, therefore, requires less intense lighting. These activities include storage areas, process water wells, outdoor tanks, service truck parking, residue and ash storage, etc. Special process equipment lighting shall also be provided to assure safe access and work illumination. Stacks shall be obstruction lighted in accordance with Federal Aviation Authority (FAA) regulations. All outdoor signs shall be illuminated.

Signage: Well-designed graphics should be used for directional and identification signing. These signs shall be properly located to achieve their purpose without constituting a hazard to vehicles or pedestrians.

Clear, concise graphic design of all directional and identification signs shall be incorporated into the design of each facility, in accordance with County standards and applicable codes of the County.

Erosion Control/Seeding and Planting: The Contractor shall establish an erosion control plan consistent with the State of Florida and Broward County erosion and sediment control requirements.

The Contractor shall establish grass and plant trees and shrubs in accordance with the Landscaping Plan as approved by the County.

<u>Landscaping</u>: Landscaping of each facility site will be used to control or screen views from adjacent roads.

Trees, shrubs, ground cover, planting, sculpture and use of building and paving materials, shall be integrated into the building arrangement, topography, parking and screening requirements.

Fencing, evergreens, shrubs, or bushes (or combinations), shall be located on the site perimeter to minimize the effect of vehicle headlights, noise, outdoor lighting glare and reflection, movements of people and vehicles, and to shield the site activities from adjacent properties where necessary.

Adequate landscaping shall be required to provide maximum screening for the sites. The landscaping plans shall address the following items:

- Earth sculpturing to provide topographic relief and to aid in screening such areas as parking lots and blank walls.
- Appropriate street tree plantings along access roads to the site.
- Extensive use of plants indigenous to Florida to provide visual screening and local color.
- Plantings to enhance the main entrance to each facility.
- Appropriate plantings around employee outdoor sitting areas.
- Preparation of soil stabilization plans for use during construction which utilizes plants and grass as stabilizers.

The selection of plant species should be based upon those plants which are tolerant of local conditions. Indigenous vegetation should be included in appropriate areas of the site. Planter boxes should be kept to a minimum. Lawn areas should be kept to a minimum with hardy ground covers utilized wherever possible. Top soil shall be provided in all planting areas and all plant pits.

A preliminary landscaping plan for each facility site is a proposal requirement. Special attention in the plan should be given to the entrance and the visitors' area, as well as the view of each facility from the public streets serving it and/or from adjacent highways.

1.4.2 Detailed Architectural Requirements

Masonry: In addition to complying with all pertinent codes and regulations, the Contractor shall comply with the standards of masonry installation described in "Concrete Block Masonry Inspectors Manual" published by the Technical Committee of the California Concrete Masonry Manufacturers Association.

Concrete Curbing: All curbs shall be constructed of concrete with suitable expansion joints. The Contractor's quality of work shall conform to the requirements of the Florida State Department of Transportation, American Concrete Institute and the American Society for Testing Materials (ASTM).

Carpentry and Mill Work: Lumber, herein referred to, shall conform with the American Lumber Standard, Simplified Practice Recommendations, latest edition. Lumber shall conform to and bear the grade and trade mark for the Association under whose rules it is produced.

Wall Panels: Wall construction shall be fabricated and installed to withstand 100 MPH wind.

Wall panels shall satisfy the following requirements:

ASTM B-117 - Salt Fog Test
ASTM D-968 - Abrasion Resistance Test
Kesternich Pollution Resistance Test
ASTM D-2247 - Humidity Resistance Test
Color Variance - Not more than 0.5 NBS units

Ceramic Tile: All ceramic tile shall be quality certified by the Tile Council of America Inc. Floor tile shall have abrasive surface. Wall tile shall be glazed surface.

All tile work shall be set in accordance with the "Tile Handbook" superseding the Basic Specifications for Tile Work K-300.

Acoustical Tile Ceilings: Acoustical tile panels shall meet ASTM C523 for light reflectance and Underwriters Laboratories Noncombustible Class 25.

Insulation and Lagging (for Exterior Mechanical Equipment): The Contractor shall furnish and install insulation and lagging for the following equipment: furnaces, boilers, precipitators and inlet ducts and nozzles, precipitators and outlet nozzles, breechings and ducts, I.D. fans and I.D. fan outlet ducts to stack, precipitator hoppers and conveyors.

The exterior lagging shall consist of flat overlapping square panels with cross-brake pattern.

The lagging shall be fastened with non-corrosive studs or clips. Closure strips, flashing and counterflashing of the same thickness as the panels shall be provided as required.

All laps of lagging, flashing and openings which cannot be made waterproof with closure strips shall be filled with high temperatures caulking compound (I-C 405) or equal, so as to render the entire lagging system weathertight.

Any additional stiffeners, corner angles, clips and other fastening and supporting devices shall be supplied as an integral part of the lagging system.

Dissimilar metals shall be insulated from one another by means of dissimilar metals separators or suitable primer and aluminum paint methods in accordance with siding manufacturer's recommendations, subject to approval of the County.

Each precipitator roof shall be adequately insulated. The roof shall be sloped to prevent rain water accumulation and shall be completely weatherproof. The insulation shall be protected by sheet metal panels, supported on purlins and designed for at least a 50 pounds per square foot live load.

Painting: Painting shall include but not be limited to the following items:

- Structural steel shapes and members
- Ferrous metal furnace castings and supports
- Electrical motors
- Cranes
- Charging hoppers, chute extension, refuse chutes and gates
- Combustion air fans and ductwork
- Stokers and siftings chutes
- Furnace access doors and ports; boiler doors and appurtenances
- Conveyors, flap gates, discharge chutes, drives
- Boiler structures and supports
- Precipitator, breechings, ductwork and I.D. fan structures
- Stack and appurtenances
- Mechanical Equipment
- Scale and enclosures
- Transport equipment
- All pipework, fittings, valves and supports
- Tanks, strainers, deaerator, steam piping, valves and pumps
- Conduit, panel boxes, pull boxes, meter boards and distribution boxes
- Partitions, doors, frames, stairs, railings, ladders, grilles, registers, air diffusers, and underside of exposed metal decking

- Wood staining of wood doors, trim, paneling, millwork and wood shelving

- Stripping of on-site road and parking lots

Galvanizing: Galvanizing shall be done by the hot dip process in accordance with the specifications of the AHDGA.

Fencing and Gates: It is the Contractor's responsibility to provide fencing along the entire perimeter of the project sites and to provide site security. Security fencing and gate controls shall be made attractive.

1.5 Structural

1.5.1 Structures Supporting Vehicular Traffic

The design, loadings, materials, allowable stresses, fabrication and construction of structures subject to vehicular traffic such as roads, ramps, underpasses, tunnels, culverts, elevated roadways and framed slabs shall conform to the current standard specifications of the American Association of State Highway and Transportation Officials (AASHTO), including all interim specifications of AASHTO, and all applicable design requirements of the County and the State.

1.5.2 Structural Steel

General Requirements: The current rules and practices set forth in the "Code of Standard Practice for Steel Buildings and Bridges" and the "Specification for the Design, Fabrication and Erection of Structural Steel for Buildings" of the American Institute of Steel Construction (AISC) shall apply to the work performed.

Quality Criteria and Inspection Standards shall conform to the AISC publication "Quality Criteria and Inspection Standards" latest edition.

Materials: Structural steel shall conform to ASTM A 36. High strength bolts, with suitable nuts and washers, shall conform to ASTM A 325. Welding electrodes shall conform to AWS Code D1.1. Stud shear connectors shall conform to AWS Code D.1. The following list indicates the minimum requirements for specific steel items:

Mild Steel Plates: Special Shapes for structural quality - ASTM-A27.

Steel Sheets: Structural quality - ASTM A 245.

Steel Plate: ASTM A 120, fittings for steel pipe shall be standard malleable iron.

Bar Steel: Hot rolled including rounds and squares of all sizes, and flat 6 inches or less in width.

Fabrication: Fabrication shall be in accordance with the applicable provisions of the AISC Specification for the Design, Fabrication, and Erection of Structural Steel for Buildings.

Connections: Standard type connections shall comply with the appropriate tables entitled "Framed Beam Connections" of the AISC "Manual of Steel Construction" and shall be used wherever possible to employ such connections.

Bolting: Assembly of structural joints using high strength steel bolts shall be in accordance with the RCRBSJ Specification for "structural joints using ASTM A325 or A490 bolts."

Welding: Welding of structural steel work and study shear connectors shall be in accordance with AWS Code D1.1.

Shop and field welding shall be performed only by certified welders qualified in accordance with AWS Code D1.1.

Field Erection: All members shall be aligned, leveled, and adjusted accurately prior to final fastening. Tolerances shall conform to the AISC "Code of Standard Practice".

1.5.3 Metal Roof Deck

Materials: Design and fabrication of metal roof deck shall be in accordance with the latest specifications of the Steel Deck Institute. Steel used in the fabrication of deck units shall conform to the requirements of the AISI "Light Gage Cold-Formed Steel Design Manual".

Field Erection: The complete metal deck, including all shaping, cutting, fitting, drilling, welding, accessories, closures, sump pans, fastenings and all other miscellaneous pieces necessary, shall be properly installed with weathertight construction. Metal deck shall be erected in accordance with the deck manufacturer's instructions.

Welding and Fastening: Welding shall be in accordance with the requirements of the AISI "Specifications for the Design of Cold-Formed Steel Structural Members" and the AWS "Structural Welding Code".

1.5.4 Miscellaneous Metals

Miscellaneous metals shall include such items as:

- Gratings (aluminum, fiberglass and galvanized steel)
- Metal Floor Plates
- Railings
- Loose Lintels and Miscellaneous Framing
- Ladders

Galvanizing of miscellaneous metal after fabrication shall be in conformance with ASTM A-123 and A-153. Cadmium plating of miscellaneous metals shall be in accordance with ASTM A-165, Type TS.

Specific requirements for miscellaneous metals include the following:

Grating: Grating shall conform to the following standards:

- ASTM A-123, zinc (hot-galvanized) coatings on products fabricated from roiled, pressed, and forged steel shapes, plates, bars and strip.
- ASTM A-385, high quality zinc coatings (hot-dip) on assembled products.

- ASTM A-569, steel, carbon (0.15 maximum, percent), hot-rolled sheet and strip, commercial quality.

- NAAMM, Metal Bar Grating Manual and Metal Finishes Manual.

- Standards of the Reinforced Plastic/Composites Institute.

- National Bureau of Standards, PS15-69.

- ASTM B-210, Aluminum-Alloy Drawn Seamless Tubes.

- ASTM B-221, Aluminum-Alloy Extruded Bars, Rods, Wie, Shapes and Tubes.

Ladders: Vertical ladders and cages shall conform to applicable OSHA regulations.

Railings: All railings (posts, rails and toe plates) shall conform to applicable OSHA regulations.

Metal Floor Plate: All metal floor plate shall conform to the applicable provisions and accommodations of the following:

- ASTM A-36, Structural Steel.

- ASTM B-209, Aluminum-Alloy Sheet and Plate.

- ASTM A-123, zinc (hot-galvanized) coatings on products fabricated from rolled, pressed and forged steel shapes, plates, bars and strip.

1.5.5 Concrete

General Requirements: The requirements of Part III of the American Concrete Institute, "Building Code Requirements for Reinforced Concrete", (ACI 318-77) shall govern the concrete work.

Materials: Portland cement shall conform to ASTM "Standard Specifications for Portland Cement", C 150, Type II.

High-Early-Strength Portland Cement shall conform to ASTM "Standard Specifications for Portland Cement", C150, Type III.

Aggregates for concrete shall conform to ASTM "Standard Specifications for Concrete Aggregates" C33.

Air-entraining admixture shall conform to ASTM C 260, and shall be used in all concrete exposed to the weather. Air entraining admixture shall be added in such quantities as necessary to produce an air content of 4 to 6 percent by volume, as determined by ASTM C 231.

Water-reducing and retarding admixture shall conform to ASTM C 494, Type D and shall be used in all concrete. The admixture shall be added to the proportions recommended by the approved manufacturer.

Water shall be clean and free from injurious amount of oil, acid, alkalies, organic materials, or other deleterious substances.

Metal reinforcement shall be deformed bars and wire mesh conforming to the following requirements:

Deformed bars - ASTM A615, Grade 60.

Wire Mesh - ASTM A 185

Testing and Inspection: Testing and inspection of concrete and materials shall be performed by an independent testing laboratory.

The Contractor shall make test cylinders of the concrete placed at the job in accordance with applicable ASTM standards. Concrete cylinder testing shall conform to the standard Method of Making Compression Test of Concrete, Serial Designation C39.

Test cylinders shall be properly cured and aged before testing. Copies of all test reports shall be retained by the Contractor for record. Cost of all tests shall be borne by the Contractor.

Proportioning and Mixing Cast-in-Place Concrete: All structural concrete shall have a minimum compressive strength of 4000 psi in 28 days. One brand of cement only shall be used to prevent different shading of finished concrete or mortars.

Ready mixed concrete shall be mixed and delivered in accordance with the Standard Specifications of the ASTM C-94 latest edition.

Temperature: Hot weather - All methods and materials used for hot weather concreting shall be in accordance with the requirements of "Recommended Practice for Hot Weather Concreting" (ACI 605).

Lightweight Insulating Roof Fill: All work shall conform with the requirements of the prevailing Building Code in addition to the requirements or qualifications of these specifications.

Lightweight insulating roof fill shall meet all requirements as detailed in:

ASTM C-332-66(71) Group I
ASTM D-312-71
Factory Mutual 69-209.20

1.5.6 Light Poles, Mast Lighting, Sign and Signal Supports

The design, loadings, materials, fabrication and construction of light poles shall conform to standard specifications for structural supports for highway signs, luminaries and traffic signals of the American Association of State Highway and Transportation Officials, and all the design requirements of the County and the State.

1.5.7 Stacks

Stacks shall be designed and erected in accordance with all applicable codes and regulations. Stacks shall include a flue for each combustion line proposed and shall also provide an extra flue for future expansion. The maximum stack height, at each site shall be 200 feet above final grade elevation. The stacks can be of a radial brick, concrete, or steel type with acid resistant high temperature liners. In all cases the stacks shall be of a design providing sufficient draft to exceed by at least twenty percent all losses due to I.D. fan outlet breeching gas velocities, in stack gas velocities and friction and stack outlet velocities. In no case shall the stack designs result in positive pressures at the base of the stacks under normal operating conditions.

The design loading for stacks or chimneys shall conform to the minimum building code requirements of American National Standards Institute (ANSI A58.1). The wind pressure shall be based on a fastest mile speed of 100 miles per hour at 30 feet above ground and Exposure C with consideration given to gusts and vibration response.

The design, materials, fabrications, and construction of concrete chimneys shall conform to the standard specification for design and construction of reinforced concrete chimneys (ACI 505).

The design, materials, fabrication, and construction of steel chimneys shall conform to the specifications of American Institute of Steel Construction and American Iron and Steel Institute with design considerations given to cable deflections.

Masonry chimneys shall be constructed with radial bricks with type "M" mortar conforming to ASTM C-270.

1.6 General Mechanical

1.6.1 Plumbing/Piping

City Water Piping: The Contractor shall furnish and install City water supply piping as required.

Hydrostatic testing for water piping shall conform to AWWA Specification C-600-64 Section 13.0.

All ductile iron pipe and fittings shall be cement lined. Linings shall conform to ANSI Spec. A 21.4. All piping and fittings shall be shop coated with standard bituminous coating on the exterior.

Reinforced Concrete Piping: Reinforced concrete pipe shall be Class IV Reinforced Concrete ASTM C-76 (Steel Area 0.07).

The installation of all pipe shall conform to the applicable requirements of AWWA Standard C600. All accessories for making mechanical joints shall meet the requirements of ANSI Specification A 21.11.

Polyvinyl Chloride Piping (PVC): All piping and fittings shall be Type 1, Grade 1, virgin unplasticized PVC Schedule 80 conforming to ASTM Des. D 1784, D 1785, D 2241, D 2264 and D 2467.

All assembly shall be done strictly in accordance with the manufacturer's specifications.

Miscellaneous Piping Requirements: Bronze gate and globe valves shall conform to ASTM B 62.

All backflow preventers shall conform to local code requirements. Air release valves shall be installed where required. All required accessories, such as gate valves, globe valves and check valves shall be installed as recommended by the air release valve manufacturer.

Wherever dissimilar metals come in contact, dielectric couplings shall be installed in the lines to separate the metals and prevent galvanic action.

The Contractor shall conduct testing of all pipelines leakage. All pipelines shall be tested to not less than one hundred fifty percent of the working pressure. All visible leaks and defects shall be promptly repaired and the line re-tested.

Drain lines on the process piping system shall be tested as per plumbing standards.

Painting: All pipelines shall be painted in conformance with latest ANSI Standards.

Temporary Water: The installation and cost of temporary water shall be provided and borne by the Contractor.

Water Meters: Water meter(s) shall be furnished and installed by Contractor. Water meter(s) shall conform to local code requirements.

1.6.2 Heating, Ventilation and Air Conditioning

Rules and Regulations: The Contractor shall conform to the rules and regulations of the BOCA Basic Building Code having jurisdiction in this State, and to all County and Local laws, ordinances and regulations affecting the erection and completion of the Heating, Ventilation and Air-Conditioning work.

Piping Installation: Piping shall be erected with proper provision for expansion and contraction, as required.

Dampers: In addition to volume control dampers, fire dampers shall be installed as required by insurance underwriters, and local codes.

Thermal Insulation for Ducts and Piping: All components of the insulation for both piping and ductwork, including facings, mastics and adhesives shall have a fire hazard rating not to exceed 25 for flame spread and 50 for fuel contributed and smoke developed. Ratings shall be as determined by Underwriters Laboratories, Incorporated, or other approved testing laboratory.

Belt Guards: Belt guards shall be installed on all equipment equipped with belt drives.

Vibration Isolation: Vibrating equipment such as pumps, fans, etc., shall be isolated from the building structure in a manner such that sound and vibration will not be transmitted through the building.

1.7 Electrical

1.7.1 Scope of Work

The scope of this section is to cover the work consisting of designing, furnishing, and installing all necessary equipment for the following:

- The interconnection system between each facility and FP&L, which shall include the outdoor switching substation consisting of circuit breakers, metering and power transformers and equipment, and all associated protection and synchronizing equipment, as well as the transmission feeders and terminating potheads between switching station and the FP&L transmission line.

- The step-up/step-down power transformers, interfacing circuit breakers and protective equipment at the switching station to meet facility and FP&L requirements. If load tap changers are required, they shall be provided in separate enclosures. Interconnect transformers shall each be sized for the full output of the plant.

- Three-phase current limiting reactors, one for each generator. The reactor shall limit the three-phase short circuit power on FP&L to FP&L requirements. The exact rating of the reactor shall be calculated by the Contractor and coordinated with the characteristics of the other equipment (i.e., transient reactance of the generators, independence of power transformers, FP&L available short circuit, etc.).

- 4.16 KV system for auxiliary services consisting of 4.16 KV switchgear, 4.16 KV motors and associated starters, and all other necessary equipment and materials required for the proper operation of the 4.16 KV system.

- 480 volt system consisting of the 480 volt switchgear, the 4.16/0.48 KV power transformers, all necessary motor control centers, energy saver type electrical motors, all necessary relaying protection with an emphasis on a properly coordinated ground fault protection system and all necessary equipment and materials required for the proper operation of the 480 volt system.

- Complete indoor relay and control switchboards for all the facility's electric systems.

- Indoor and outdoor lighting systems comprising all necessary equipment and materials required for the proper illumination of the plant and site, at the required illumination levels for each specific task.

- 125 volt DC system consisting of 125 volt DC battery, the required charger and the appropriate DC distribution switchboard.

- Cable and wiring system with all necessary raceways for all power distribution systems, including reinforced, concrete encased, underground duct banks, and exposed AC and DC conduit system with rigid galvanized steel conduits and approved fittings. This shall include excavating, dewatering and backfilling. All cable and terminations shall be in accordance with the manufacturer's specifications.

- Control, security and communication systems, Telephone, Fire Alarm, Smoke Detection, Sprinkler, Halon, Lighting, Local Automatic Shutdown, Local Manual Control, Central Automatic Control, Security, and HVAC for all plant and auxiliary operations, all as described elsewhere in these specifications.

1.7.2 General Electrical Requirements

The following items of equipment covered by this specification may be installed either indoors or outdoors in the open atmosphere:

- Turbogenerators and associated power generation equipment.
- 4.16 KV A.C. switchgear and accessories.
- 480 volt A.C. switchgear and accessories.
- 124 volt D.C. battery system.
- Interconnection bus structure, insulators, bus switches, etc.
- Interconnection oil circuit breakers.
- Interconnection power transformers.

The Contractor shall furnish, install and connect any additional components, parts, items and devices not specifically mentioned herein, but necessary for the proper operation of the equipment.

The systems shall be provided in accordance with all local and federal code requirements and shall provide the functional features described. Each system shall be furnished and installed complete with all appurtenances necessary to be fully operational.

1.7.3 Standards

All equipment to be furnished by the Contractor shall be in accordance with the latest applicable standards of NEMA, IEEE, ANSI, AAR, IPCEA, latest OSHA, UL, National Electrical Code, National Electric Safety Code, Florida Electrical Code, and all applicable local codes and/or ordinances with regard to Material, Design, Construction, Testing and Installation except for variations as specified herein.

1.7.4 Temporary and Interim Electric Work

The Contractor shall provide temporary, electrical services required for construction of the Project, including all fees to FP&L for their work associated with such electrical services and connections. FP&L energy use charges shall be paid for by the Contractor.

The installation shall conform to the requirements of FP&L and shall include poles, post, fences, grounding, terminations, meter cabinets, meter and secondary feeder and branch wiring and conduits, circuit breakers, panelboards, lights, wiring devices, wiring, motor connections and supports.

1.7.5 Cutting and Patching

The Contractor shall furnish chases and openings in the floors, walls, and partitions before they are built. The Contractor shall install sleeves or boxes in the forms of floor slabs and/or walls before they are poured.

1.7.6 Fire Alarm System

The Contractor shall equip each facility with a fire alarm system, including all necessary manual stations, bells, control panel and annunciator, wiring and conduit.

1.7.7 Fail-Safe Systems

The Contractor shall install Fail-Safe Systems for all key equipment, including, but not limited to the furnaces, the boilers, turbine-generator set, the electric substation and the electrostatic precipitators. The Fail-Safe Systems of each key equipment item shall be so designed that if any one piece of equipment fails, other equipment will not be damaged by this failure.

1.8 Facility Access and MSW Delivery Requirements

1.8.1 Functional Design

Each facility site design shall provide adequate ingress and egress roads and maintain continuous control of all traffic movements during facility operating hours. Each facility design shall also include adequate on-site roadways, parking, and maneuvering areas to accommodate, efficiently and safely, anticipated traffic levels during normal and emergency periods, in order to minimize the impact of traffic on noise and air quality levels and to prevent the queuing of disposal vehicles on public roads adjacent to the facilities.

1.8.2 Traffic Flow

The MSW will be delivered to each facility by collection trucks that are either municipally or privately operated.

On-site traffic shall be directed generally using one-way roads either to the weighing stations (MSW trucks), the ash handling areas (residue truck), and/or to the administration areas and process buildings (staffs, visitors and all other vehicles). This one-way flow of traffic shall help ensure congestion-free operations and smooth-functioning facilities.

MSW trucks shall proceed from the entries to the weighing stations, establish the weight of the refuse, proceed to the tipping areas for unloading, stop at the weighing stations again, if necessary, and then exit the facilities.

Trucks hauling Unprocessable Waste shall proceed from the entries of the resource recovery facilities to the weighing stations, establish the weight of the Unprocessable Waste, proceed to the Residue/Unprocessable Waste landfill dumping areas for unloading, stop at the weighing stations again if necessary, and then exit the facilities.

Two-way roads may be planned for on-site roads at the resource recovery facilities to the Residue/Unprocessable Waste landfills.

Maintenance and delivery vehicles shall be directed to the plant office or to service areas within each facility.

Paving and drainage of parking areas shall be in accordance with accepted standards. Staff and visitor vehicles shall be directed to parking adjacent to the administration area immediately upon entering each facility to prevent any traffic conflict with truck flows.

Roadways for trucks shall serve the scale house areas, the tipping floors and other functional areas of the facilities. Roads within each facility shall be designed to allow proper traffic flow to prevent the queuing of waste-handling vehicles, both during normal operation and in the event of mechanical failure of vehicles or at the scale house. Access to the sites from adjacent roads shall be designed to minimize interference with exiting traffic flow and permit vehicles rapid and safe ingress and egress to and from the sites. Sufficient on-site roadways shall be provided to ensure that traffic backups will not extend out to the local streets or highways.

The traffic design for each facility shall be based on the following criteria:

- o A daily quantity of delivered MSW determined by the following formula:

$$DW = \frac{AFT \times AF_1 \times AF_2 \times AF_3}{365}$$

Where:

DW = Quantity of delivered MSW (processable and unprocessable waste) per day in tons

AFT = Annual guaranteed facility throughput in tons of Processable Waste

AF_1 = MSW Delivery Adjustment Factor = 1.17

$$\left(\frac{\text{7 days per week operation}}{\text{6 days per week delivery}} = 1.17 \right)$$

AF_2 = Broward County seasonal MSW generation rate Adjustment Factor = 1.11

AF_3 = Broward County Peak Daily MSW Delivery Adjustment Factor = 1.43

- The estimated number of trucks delivering garbage shall be based upon 55 percent of DW as determined above and an average net load of 9.0 tons per truck.
- The estimated number of trucks delivering processable trash shall be based upon 23 percent of DW as determined above and an average net load of 5.0 tons per truck.
- An estimated quantity of residue based upon such residue containing not more than 4 percent combustibles and 0.2 percent putrescibles of the incoming MSW.
- The estimated number of trucks delivering unprocessable trash shall be based upon 22 percent of DW as determined above and an average net load of 5.0 ton per truck.
- An estimated volume of 75 employee and visitor cars per day. Visitors arriving by bus shall also be accommodated.
- Maintenance and delivery vehicles as required.

Proper access shall also be provided for fire fighting apparatus. There shall be a bypass road around each scale house area for fire fighting, passenger and other designated vehicles.

All access roads used by refuse vehicles shall be constructed and paved in accordance with standards for heavy truck usage.

The Contractor shall maintain weighing, receiving, and queuing areas which are capable of:

- Accepting the refuse in the quantity proposed and assumed transport mix.
- Completing the functions of the MSW delivery (entering the plant, weighing, unloading, and exiting the plant) within ten (10) minutes of each truck arrival at the site; even during peak arrival periods.
- Receiving, holding, or processing normal MSW quantities during scheduled downtime.

Adequate parking and maneuvering areas shall be provided for both facility staff and visitors. Provisions for the handicapped shall also be made for parking and sidewalk access.

The design and operation of all vehicular activities and traffic flow patterns associated with the construction and operation of each facility will be subject to the regulations of state and local Traffic and Highway Departments.

1.8.3 Traffic Control

The traffic flow within each facility site shall be controlled by stop signs except at the plant entrances, the weighing stations, and the tipping floor area where traffic lights shall be installed. All routine traffic shall be directed utilizing one-way roads. There shall be a minimum of mixing of truck traffic with staff and visitor traffic. There shall be exclusive truck routes to handle the estimated number of trucks per day including all refuse trucks, residue trucks, unprocessable waste trucks, maintenance and delivery vehicles. Provide a truck turn-around in clear view of the scale operator for diverting unacceptable loads of waste.

The traffic pattern at each facility shall be designed to provide for efficient operation and use of space. The weighing systems and storage facilities may be of whatever design is most applicable to the process needs, while meeting the efficiency and safety specification.

Identification signs at the entrance and appropriate directional signs which are approved by the County shall be provided. Fences, gates, metal doors with locks, card controlled gates, or other adequate security measures must be provided to control access to each facility.

1.8.4 Weighing Station

General Information: The intake of waste to each facility shall be regulated and controlled by its weighing station's operation. MSW will be transported to the facilities either in municipal collection vehicles or private carter trucks. The facilities will not accept hazardous waste, and private automobiles will not be permitted to dump MSW at the facilities. After weighing, Unprocessable Waste shall be directed to the Residue/Unprocessable Waste landfill. In the event Unprocessable Waste is inadvertently unloaded at the resource recovery facility, the Contractor shall be responsible for cost of transporting such waste to the Residue/Unprocessable Waste landfill.

Deliveries shall be made in accordance with the County's normal collection and delivery practices as now or hereinafter may exist. Safe and adequately-sized areas must be provided for queuing incoming trucks and to prevent traffic back-up from interfering with local street and local highway traffic flows.

Each facility shall have the capacity to unload the Processable Waste from the vehicles, in a totally enclosed tipping area, with a total on-site unloading time of ten (10) minutes for mechanically unloaded vehicles. The unloading time is defined as the time a vehicle first enters the site to the time the vehicle leaves the site.

The Contractor shall maintain an identification system, including scales for weighing and recording deliveries. The scales shall be of a type approved by the State Sealer of Weights and Measures and shall be equipped with automatic printers which shall record the time, date, and scale weight in accordance with the Contractor's identification and accounting procedures.

The number of scales at each weighing station shall be determined using the information for truck flow; queuing space determined by the Proposer, the ten minute time per vehicle as defined above; and the inclusion of one standby scale.

Each weighing station shall be fully automatic with manual override systems. Each weighing station operator shall serve as the equipment operator as well as the traffic flow controller to the tipping area, and also maintain a level of security.

Each weighing station shall consist of as a minimum, but not be limited to, truck scales, scale pit or foundation with understructure and weighbridge, scale house, truck identification system, scale house equipment, approaches, entrance and exit gates and traffic control signal system.

Approach Road: The approach road to the weight station shall be wide enough to "fan" out the incoming flow of traffic as well as serving as a by-pass should any vehicle breakdown.

A deceleration lane shall be provided to ensure that traffic will not back up onto public streets.

The by-pass road for vehicles not having to be weighed (employee, visitor, delivery and maintenance vehicles) shall be controlled by a gate, which shall be manually operated by the weigh scale operator.

Scale Design: The truck scales shall have, as a minimum, a capacity of 70 tons and shall automatically print out vehicular weights on scale tickets. Each scale shall be equipped with an indicating and recording system.

Upon entering each facility, each delivery vehicle shall be weighed. If tare weights have not been established for particular vehicles, these vehicles shall be unloaded and weighed upon leaving the site. Therefore, provisions for scales to be used upon exit shall also be provided.

Scale Houses: The scale houses shall include all equipment which is auxiliary to the scales, such as the digital indicators, card printers with printout of gross, tare and net weights, and an accumulator for daily totals of net weights. These facilities shall include restrooms for truck drivers and employees, as well as visitors' observation spaces.

1.8.5 Tipping Area

General: The Processable Waste tipping process shall take place in totally enclosed tipping areas, which shall have a minimum length equal to the Processable Waste receiving and storage pit, and which shall be kept under negative pressure.

Ventilation systems shall provide for the control of dust, and shall meet all applicable Occupational Safety and Health Administration (OSHA) requirements for ventilation. In addition, sound proofing shall be provided within the tipping floor areas to limit the maximum noise level to 80 decibels (dba).

Truck Tipping Bays: At each facility there shall be an adequate number of tipping bays (to be determined by the Proposer) to handle the peak flow of waste trucks at all times. The number of bays should be based on the maximum vehicle size; peak truck flow; the coordination of queuing space at the weigh station, and the ten minute on-site time from entering the facility at the gate to exiting at a gate.

Safety and Hazard Controls: Safety measures shall be provided to minimize noise, dust, odors and general hazards, such as fire, in the tipping areas. Efforts shall be made in the design of each facility to maximize safety. All applicable requirements of OSHA shall be met with regard to the tipping area.

1.9 Processable Waste Storage and Handling System

1.9.1 General Description

At each facility, Processable Waste shall be stored in a pit large enough to hold, as a minimum, four times the daily Nameplate Capacity of the facility, based on an in-pit density of 500 lbs per cubic yard and without exceeding the elevation of the tipping floor. Minimum volumes shall be 24,000 cubic yards at the north plant and 32,000 cubic yards at the south plant.

At each facility, Processable Waste shall be moved from the storage pit and fed or charged into the furnaces by means of an overhead crane and grapple system. The cranes and grapples will also be used to mix Processable Waste in the pit to produce a homogeneous mass and shall be capable of removing large, bulky items from the storage pit. Provisions shall be made for removal and disposal of such items.

1.9.2 Processable Waste Storage

Construction: The pits shall be constructed of reinforced concrete and take into account soil, groundwater and flood-prone conditions of the sites. The crane parking areas shall be of prestressed concrete with steel reinforced outer perimeters.

The foundations of the pits shall be isolated and the independent of the foundation of the process buildings.

Dust and Odor Control: The pit areas shall be totally enclosed to limit the spread of any odor and dust. The areas shall be kept under negative pressure by drawing combustion air from the pit areas using the combustion air fans.

Ventilation Systems: The ventilation of the tipping areas as well as the pit areas shall be accomplished by the combustion air fans used for all the furnaces. Make-up air louvers, with broad screens shall be provided as required.

Fire Protection: There shall be at least two types of firefighting equipment for control of both chemical and non-chemical fires (water cannon and standpipe system). There shall also be fire alarms provided which shall be tied directly to the local fire departments in the event of any pit fires.

1.9.3 Crushers/Shears (Optional)

At each facility a crusher/shear may be provided for size reduction of oversized combustible bulky waste down to a size which shall minimize bridging or clogging in the furnace charging hoppers and assure complete incineration as fired with processable waste.

1.9.4 Crane and Grapple Systems

Scope: At each facility there shall be two 100 percent or three 50 percent capacity (one spare) heavy duty electric overhead traveling cranes suitable for continuous service handling Processable Waste.

The cranes shall be remote controlled from a stationary pulpit. "Cab-on-Crane" arrangements will not be permitted. Radio controlled cranes will be permitted.

Codes and Specifications: Unless otherwise specified, the cranes at each facility shall be designed and manufactured in accordance with applicable codes, manuals, specifications and requirements for Severe Duty Cycles and Steel Mill Type of Service:

(a) American Gear Manufacturers Association (AGMA)

(b) American Institute of Steel Construction (AISC)

(c) American National Standards Institute (ANSI)

(d) American Welding Society (AWS)

(e) Anti-Friction Bearing Manufacturers Association (AFBMA)

(f) Crane Manufacturers Association of America (CMAA) - Specification No. 70 (Electric overhead traveling cranes, Severe Duty Cycles.)

(g) Insulated Power Cable Engineers Association (IPCEA)

(h) National Electrical Manufacturers Association (NEMA)

(i) National Fire Protection Association (NFPA)

(j) Occupational Safety and Health Administration (OSHA)

(k) Steel Structures Painting Council (SSPC)

(l) American Society for Testing and Materials (ASTM)

(m) Association of Iron and Steel Engineers (AISE) - Standard No. 6 (May 1969) Specification for electric overhead traveling cranes for Steel Mill Service

In case of conflict between various applicable codes, standards and regulations outlined in this paragraph, the "Specification for Electric Overhead Traveling Cranes for Steel Mill Service" AISE Standard 6 of May, 1969 shall govern.

<u>Rated Capacity</u>: Each crane capacity shall be based on the weight of the grapple including lifting cables, plus material.

<u>Design Stresses</u>: The cranes shall be mechanically and structurally designed and fabricated in accordance with AISE specifications for steel mill service. Unless otherwise specified, the design stress conditions shall be those required under codes and specifications above.

<u>Duty Cycle</u>: Duty cycle computations shall be based on:

Furnace Feeding	43%
Restocking	17.0%
Fatigue	10%
Total Active Time	70.0%

The cranes shall be capable of performing continuously, the feeding and rehandling cycles with full load, with motor temperature rises not exceeding the specified rating of the motors. The following crane/grapple motions may take place simultaneously:

- Hoisting and bridge travel with grapple at any level.
- Lowering and bridge travel with grapple at any level.
- Trolley and bridge travel with grapple in high position.

In addition to the simultaneous motions outlined above, the normal crane operations shall permit the following functions:

- Grapple open and close at any level.
- Trolley and/or bridge travel with grapple at any level.

Environment: The cranes shall be designed for an indoor dusty environment.

Crane Parking: The crane runways shall be designed to allow for parking of one crane at each end of the pit when out of service for repairs or for inspections. The roof above the crane runway shall include a penthouse with service platforms for each additional crane over and above the two cranes that can be parked at each end of the runway. The penthouse(s) shall include electric hoists to lift an inactive crane from the runway for parking or maintenance.

Operator's Pulpit: There shall be a minimum of one remote, stationary operating station (operator's pulpit) located above the pit on either the tipping floor or hopper side, which allows full view of the storage pit and of the furnace charging hoppers. The operating station shall contain one operator's control chair for each crane installed.

All station access corridor enclosures, separating station corridors from the refuse storage pit, shall be dust tight. The stations shall be equipped with an independent heating, ventilating and air conditioning system in accordance with the applicable building code requirements.

The pulpit shall be equipped with fire alarm systems, indicating panels and fire fighting control capabilities. There shall be a direct phone line to the local fire department from the operator's pulpit.

The normal crane operation shall provide for automatic loction of the trolley and bridge over the selected charging hopper after the grapple has picked its load and ahieved its lift to the top elevation.

Each crane shall be operable from either control pulpit on demand except when in use by one of the operators. A traverse switch shall be provided which will enable any one crane to be operated from any operator's station. Interlocks shall be provided to prevent interference and attempts for simultaneous operation.

Grapples: Orange peel or clam shell tine type electrohydraulic grapples shall be provided for each crane with one spare at each facility, in addition to the one on the spare crane.

Electrical Motors: All motors shall be capable of starting and operating under any conditions within the design capacity of the crane and with any voltage within plus or minus ten percent of the rated voltage.

All motors shall be totally enclosed, air over housing fan cooled.

1.9.5 Charging Hoppers and Chutes

Charging Hoppers: Charging hoppers shall be designed to withstand the weight of the refuse as well as the vertical and horizontal impact of the fully loaded crane grapple.

Charging hoppers shall be independently supported by the charging floor structure and shall be arranged so as to mnimize spillage onto the charging floor. Spill plates shall be incorporated between the charging hopper and refuse pit wall.

Charging hopper discharge throat (exit) shall be smaller than furnace feed chute entrance to furnace/boiler to prevent clogging (bridging) a furnace/boiler entrance, and shall be adequately sized to accommodate individual furnace/boiler rated throughput capacity.

Chutes and Cut-Off Gates: Chutes connecting charging hoppers and furnace/boiler feed throat shall be either water cooled or refractory lined.

Chutes shall be of the inverse taper type to preclude clogging (bridging) in chute.

Between each charging hopper discharge and chute entrance there shall be a cut-off gate to prevent burnback during furnace/boiler shutdown.

1.10 Combustion Systems

1.10.1 General Design

The combustion systems and all related equipment for each facility shall be supplied by the Contractor. The minimum combined total nameplate rated capacity of the two facilities shall be 3,500 tons of Processable Waste per day. The combustion units proposed shall be of proven design with a minimal successful operating experience of one year. Scaling up of components shall not exceed 25 percent.

The Contractor shall furnish and install a minimum of three combustion units at the southern facility and two combustion units at the northern facility, each with the capability of operating five percent above its rated Nameplate Capacity. The use of multiple units is intended to provide for system redundancy and the capability of selling additional energy to the utility during peak hours of operation. THE PROPOSER SHALL PROVIDE A FIRING DIAGRAM AND ADDITIONAL INFORMATION INDICATING HOW THE BOILERS WILL BE CAPABLE OF HANDLING FLUCTUATIONS IN BTU AND MOISTURE CONTENT AS WELL AS PROXIMATE AND ULTIMATE ANALYSIS.

The Contractor shall provide the turndown ratio such that the boiler efficiencies do not drop below 85 percent of the boiler design efficiencies.

All furnace equipment and auxiliary equipment shall be manufactured and constructed in accordance with ASME boiler and furnace construction codes except where otherwise stated, and shall be so stamped on the equipment.

The individual units shall each be designed to operate at the minimum excess air level and exhaust the combustion flue gases from the electrostatic precipitator at a minimum of 40°F above dewpoint.

The minimum combustion temperature shall be 1,500°F and temperature shall be controlled to a maximum of 1,800°F.

1.10.2 Furnace Design

General: Furnace design shall be of the mass-burn stoker-fired, or stoker/rotary kiln tandem type, capable of firing as-received Processable Waste (without auxiliary fuel burning) on a continuous feed basis.

Each combustion train shall be equipped with an individual multiple pass waterwall type boiler of a configuration which has been successfully demonstrated in commercial operation.

Refractory Enclosures: The refractory linings of the furnaces, where applicable, shall be of super duty quality, laid in high temperature mortar. The refractory walls (other than rotary kiln) and arches shall be of the sectionally supported type, anchored with high temperature alloy anchors and insulated with an adequate amount of insulation.

The refractory enclosure materials shall conform or be equal to the latest of the following minimum requirements and classification:

- o Super duty fire brick - ASTM C-27
- o Silicon carbide walls - ASTM C-106
- o Insulating brick (where applicable) - ASTM C-15
- o Insulating castable - ASTM C-401, Class Q
- o Expansion joint filler - Fiberfrax, Kaowool or equal
- o Sectionally supported wall and arch mortar--Superduty Fireclay
- o Insulation - Mineral wool block
- o Tile engaging castings or anchors - ASTM A297-74A

All sectionally supported walls and arches shall be supported on a steel structure independent of stoker supports and assemblies. The exterior surfaces of the wall shall be protected by suitably reinforced steel or aluminum casings.

All structural steel framing shall be designed, fabricated and erected in accordance with the AISC Steel Construction Manual (latest edition), and in accordance with applicable local code requirements, including seismic, impact, laterial, vertical and longitudinal loading.

Grates (Stokers): The grates shall be of manufacturer's design and shall be of a design used in successful operation.

The design of mechanical components and selection of construction materials shall be such as to yield ninety percent availability under normal operating conditions. Routine repairs and adjustments shall not require more than 200 man-hours with major overhauls required at a maximum of every three years (or 20-30,000 hours).

All grate operations (speed, cycle frequency, etc.) shall be arranged for remote operation from a central control room with local manual override. Grate drive shall be by hydraulic motor controlled by a variable volume pump. The degree of burnout on the grate sections shall be established and guaranteed by the Contractor. The combustion efficiency of the stokers shall yield a residue containing not more than 4.0 percent combustibles and 0.2 percent putrescibles.

The stoker surface materials shall conform to the following minimum requirements:

- Reciprocating stokers shall be of precision ground cast chromium alloy steel grate bars.
- Feed sections not exposed to burning fuel bed - MEEHANITE HS type cast iron or equal.
- Circular grates may be cast iron.
- Parts designed to prevent erosion of side walls (if applicable) extending not more than six inches above stoker surface-MEEHANITE HS type cast iron or equal.
- Burning section castings exposed completely or in part to burning fuel bed not more than forty five percent of operating cycle time, each cycle not exceeding five minutes - MEEHANITE HS type cast iron or equal.
- All other surface castings - heat resistant alloy conforming to ASTM A 297-74a Grade HF designation.
- Alloy (weldable stainless steel) steel grates shall have a minimum of four percent nickel composition.
- Wear plates shall be "NT" (high density forged steel plate).

Waterwall Enclosures: Waterwall enclosures shall be of gas-tight fully-welded membrane type, backed by mineral wool block insulation. The cold face of the insulation shall be protected by steel or aluminum casing.

Where the waterwalls are expected to be exposed directly to direct flame or alternate reducing and oxidizing atmosphere, the tubes shall be protected with silicon carbide low oxidizing grade castable refractory, anchored to the tubes with welded studs of high temperature alloy steel.

The tube arrangements shall be of an in-line pattern (staggered tubes are not acceptable). Each boiler shall be equipped with a tube-cleaning system to provide and ensure high operating efficiency.

The walls adjacent to the stoker surfaces shall be of watercooled silicon carbide tile extending a minimum of four feet above the grate surfaces.

1.10.3 Combustion Air System

The combustion air systems shall be designed to control automatically the furnace temperatures within +50 degrees Fahrenheit of the set-point temperature selected by the Proposer while firing Processable Waste with higher heating values (HHV) varying from 3,500 to 6,000 BTU/lb. The Proposers should note the wide range of HHV for the Processable Waste as fired. Sampling conducted on Broward County's Processable Waste indicates that the minimum and maximum extremes of the range may be realized on a sustained seasonal basis (e.g. November through April at upper range and May through October at lower range) as a result of significant variation in moisture content associated with extremes in rainfall.

The distribution of the primary and secondary air, including secondary air jets, shall yield a combustion efficiency resulting in dry gas carbon monoxide (CO) content not exceeding 0.1 percent by volume, measured upstream of boiler convection sections.

Separate fans for primary and secondary air shall be used (minimum two combustion air fans per boiler). Each fan shall be motor driven. All combustion air fans shall be mounted on vibration elimination bases with non-combustible flexible connections at the inlets and outlets of the fans. Either system shall be automatically controlled by a furnace temperature control system. The control of the primary and secondary air flow shall be automatic with a manual override system in the plant control room.

The combustion air ductwork inlets shall be arranged to use selectively air from the refuse storage area, tipping area, or from outside atmosphere, or any combination of the above. Each primary and secondary air inlet duct shall be fitted with venturi type or similar non-plugging type flow measuring device with remote output readout instruments.

The combustion air ductwork shall be manufactured of sheet metal or steel plate two gauges thicker than required by ASHRAE code for air conditioning and ventilating systems for a similar air capacity and pressure. Section joints shall be flanged and gasketed; access doors or panels shall be provided at each bend; the ductwork system shall be essentially air tight with leakage not exceeding one percent of the maximum design air flow.

The fan drives shall be selected for a minimum of 125 percent of the maximum design brake horsepower (BHP).

1.10.4 Energy Recovery Systems

The steam parameters for the boiler system shall be determined after fully considering their effect on causing high temperature corrosion on superheaters.

Boilers: The boiler design and manufacture shall conform to the ASME boiler code and approved quality assurance program, and, if required by applicable codes, shall bear the ASME stamp.

The boilers shall be designed with in-line tubes and drum(s) perpendicular to the gas flow. Boiler tubes shall be of an adequate tube thickness and diameter with proper spacing provided between the tubes. Adequate air circulation near the convection tubes shall be provided. Gas temperatures coming into contact with the external tubes should not exceed 1,600°F.

Single pass boilers with vertical tubes shall have an arch or stainless steel baffle to redirect the air flow and prevent excessive corrosion of the boiler side tubes. Properly sized valves with welded packing shall be provided.

The tube and drum configuration shall be the option of the Contractor, but shall conform to general requirements specified herein. The drums shall be Class 1 fusion welded construction, tested before shipment. The steam drums shall be fitted with steam separation baffles yielding dry steam with a purity of one parts per million (ppm) solids at maximum continuous steaming conditions, at the design pressure and temperatures, when the boiler water concentrations do not exceed standard ABMA limits. Each drum shall have two manhole openings fitted with hinged steel manhole covers complete with necessary bolts, grabs, and gaskets.

Proper provisions shall be made for thermal expansion of the drums so that abnormal stresses are not produced on either the pressure parts or in the supporting members. The boilers shall be designated with either a soot blowing system or tube rapping system for the cleaning of both the external and internal surfaces. An access door allowing for inspection and maintenance of the tubes and the tube rapping system shall be provided.

Superheaters: Superheaters shall be manufactured out of the alloy best suited to resist thermal corrosion as well as chlorine, fluorine and sulphur corrosion. The Contractor shall specify whether the superheater tubes will be provided with clamp protective metallic shields on the tubes at the vulnerable locations or if the tubes will use plasma-gun coating by metallic or ceramic materials.

The superheaters shall be designed with proper provisions for thermal expansion and with attemperators between the stages of the superheater. The superheater bundle shall be placed away from the primary radiant section.

Economizers: Each boiler unit shall be provided with the proper tubular economizer. The economizers shall be the bare tube type (no finned tubes).

The economizers shall be designed for forced circulation, which is provided by the boiler feed pumps, using at a minimum, a feed water temperature of 250°F. The economizer design pressure shall be at a minimum of 125 percent of the boiler design pressure. The economizers shall conform, as a minimum, in all respects to the ASME boiler codes.

1.10.5 Boiler Auxiliary Systems

Boiler Auxiliaries: The Proposer shall provide all required auxiliary systems to make the boilers complete, operable and maintainable. All boiler appurtenances shall be designed to operate and support each facility at its maximum continuous rating.

Boiler auxiliary systems, including, but not limited to all steam circulation and distribution piping, boiler feed water pumps, treated water pumps, raw water pumps, condensate pumps, tanks and accessories, water treatment and deaeration systems, boiler feedwater heaters, process piping systems, etc., shall be designed and furnished by the Contractor in accordance with:

- ASME boiler construction codes.
- Report on the identification of power house piping.
- U.S. Environmental Protection Agency (USEPA) - noise level of vent, etc.
- Maximum boiler water concentrations, recommended by American Boiler Manufacturer's Association (ABMA) chemical feed system.
- ABMA boiler standards.
- AISC manual on steel construction.
- ASHRAE standards.

Boiler Trim: Each boiler unit shall be furnished with boiler trim, in accordance with the ASME code requirements as well as conforming to the best standards of power plant practice. Trim shall be designed for a minimum of 125 percent of the nominal operating pressure (PSIG). Each boiler unit shall have manual override systems, which also overrides the boiler auxiliary equipment, located and operated from the plant central control room.

The following list of accessories, at a minimum, are required. The final number and type of accessories shall be determined by the Contractor based on the water circulation and steam distribution designs.

- Safety valves as per ASME code.
- Water column, feed water regulator, gauge and glass drain valves.
- Reliance water column with high and low alarm and water gauges.
- Low-water cutoff.
- Water column drain valves and water gauge drain valves, rated for twice the operating pressures.
- Feedwater regulatory by-pass and drain valves.
- Feedwater stop and check valves.
- Drum blow off valves.
- Boiler air vent valves.
- Chemical feed valves.
- Continuous blowdown stop and check valves.
- Tube rapping - elements, supply and drain valves (if required).
- Steam and water flow transmitters.
- Differential level transmitters.
- Computing relays.

- Auto-manual set point control station.
- Air sets.
- Main steam non-return valves.
- Feedwater control valves.

Superheater Steam Piping Systems: The high pressure superheated steam piping systems shall be designed in such a way that the pressure drop between the main steam valve of the boilers and the main valves of the turbine, does not exceed ten percent of the nominal boiler pressure and that the drop in temperature does not exceed 10°F. A loop header shall be provided to insure the most flexible mode of operation as well as maintenance.

Reducers and coolers of steam pressure shall be installed so that each facility can bypass the turbines. There shall be no steam released directly into the atmosphere except where silencers are installed to reduce the noise level below 80 decibels (dba). The condensate drainage system of the high pressure superheated piping system shall be designed such that the condensate is recovered.

Feedwater Systems: The feedwater treatment systems shall be capable of handling a minimum of 100 percent of each facility's make-up water requirements. The systems will treat water to meet each facility's boiler water quality requirements.

There shall be ONE HIGH PRESSURE BOILER FEEDWATER PUMP FOR EACH BOILER AND ONE STANDBY (BACKUP) PUMP FOR EVERY TWO BOILERS INSTALLED. High pressure boiler feedwater pumps SHALL BE EQUIPPED WITH DUAL (ELECTRIC AND STEAM) DRIVES. The feedwater system shall be designed in such a manner that achieves the maximum flexibility within the system.

The pumps shall be designed for operation at a maximum water temperature of 350°F, unless the Contractor's designed thermodynamic cycle demands otherwise.

Deaerator Systems: The water deaerator systems shall be designed in accordance with the applicable ASME codes. The deaerator storage tanks shall have a minimum ten minutes of storage of the plant's full load. The working pressure shall be suitable for the designed thermodynamic cycle of the facility. THERE SHALL BE TWO, 100 PERCENT CAPACITY DEAERATORS. The Contractor shall specify and guarantee the oxygen and carbon dioxide (CO_2) removal at any load between five percent and one hundred percent of the rated capacity. The Contractor shall also specify the amount of steam loss while the oxygen and CO_2 is being released through the deaerators. The Contractor may supply and install steam accumulator systems in order to avoid a severely fluctuating steam flow caused by the variation in the Processable Waste Btu/lb content.

Condensate System: Surge tanks for receiving the returnable condensate from the process shall be provided by the Contractor. The size and number of surge tanks depend on the amount of condensate returned and shall be determined by the Contractor. The returnable condensate is that condensate which can be reused without any major form of treatment.

Special Requirements: Boiler auxiliary equipment items shall have as a minimum the same degree of availability and reliability as the facility. Where necessary redundancy of any auxiliary equipment is required, it shall be supplied in the form of spare units.

All auxiliary equipment shall be automatically controlled with manual override systems, all of which shall be controlled from the facility's central control room.

Water Usage, Quality and Treatment: This section pertains to water that is to be used as:

- o Make-up water for steam generating systems.
- o Internal facility consumption (domestic and process uses).

Boiler water for the northern facility may be supplied by water lines from the Broward County water system. Table A-3 in Section 1.2.7 of this appendix, presents the 1982 annual average for water quality values for the County's System 1-A.

Water service by either Broward County or the City of Fort Lauderdale to the southern site may be possible. Tables A-1 and A-2, also in Section 1.2.7 of this appendix, provide annual average water quality values for the System 3-A plant (Broward County) and Walter E. Peele Plant (City of Fort Lauderdale), respectively.

1.10.6 Combustion Controls

At each facility controls shall be provided to monitor water level, furnace combustion temperature, steam flow, and exhaust gas temperature and volume. Combustion air modulation shall also be provided.

Controls shall consist of systems for Remote Automatic, Local Manual, and Remote Manual modes.

1.11 Residue Handling Systems

1.11.1 General

The solid residues from each facility must be managed and disposed of according to Federal and State standards for resource recovery facilities. The Proposer shall indicate the quantity and composition of residue ash expected to be produced at each facility from the furnace/boiler and air pollution control systems. The Contractor shall be responsible for ensuring that this residue ash, will not be considered hazardous based on applicable Federal and State regulations and requirements.

The Contractor will also be responsible for residue removal, transportation and landfilling, and all testing necessary to determine whether the residue is hazardous according to the applicable Federal and State regulations.

1.11.2 Description

The purpose of the residue handling systems is to collect the post-incineration bottom ash and fly ash while separating any recyclable materials in a dust free manner. THE SYSTEMS SHALL HAVE TWO, ONE HUNDRED PERCENT CAPACITY ASH CONVEYORS to transport the ash to the handling areas at each facility.

Provisions for tractor-trailer loading in an enclosed area, with ventilation and dust control shall be incorporated into the design. A clamshell-type bucket for loading ash onto trucks from an ash storage pit may be provided.

The Proposer shall indicate the marketability of ash, if any. THE RESIDUE ASH SHALL CONTAIN LESS THAN 4.0 PERCENT COMBUSTIBLES, AND LESS THAN 0.2 PERCENT PUTRESCIBLES. The residue shall be such that it will not support any type of animal or vermin life and will not sustain combustion.

1.11.3 Bottom Ash

The Contractor shall design the furnace connection of the ash discharge chute to be the full width of the final grate section to prevent blocking of the chute from the burn-out grate section. The distance from the end of the stoker to the furnace rear wall shall be at least equal to the height of the boiler feed throat lintel above the stoker feed section.

The bottom ash or residue shall be water cooled by spray or quenched in tanks or sumps before it is handled by the conveyors. The cooled bottom ash handling systems shall consist of drag or vibrating conveyors designed to handle the total plant load.

The Proposer shall specify water usage for residue quenching. Boiler blowdown may be used for ash quenching.

After removal of the residue ash from the water cooling system by the conveyors, the residue ash may be moved from the furnace/boilers to the ash storage area by either drag, belt, or vibrating conveyors designed for heavy duty service.

The drag conveyors, if included in the proposer's design, shall be extra heavy duty type with double strands (chains), steel flights, and with drives of the hydraulic infinitely variable speed type.

The vibrating conveyors, if included in the proposer's design, SHALL BE NATURAL FREQUENCY, balanced type, not requiring special foundations.

The belt conveyors, if included in the proposer's design, shall be of a trough type.

All conveyors shall be equipped with safety devices and zero speed switches.

1.11.4 Fly Ash

The fly ash may be combined with quenched bottom residue ash removed by the residue ash conveyors. Separate collection of the fly ash may be utilized should the Proposer wish to market the fly ash for re-use.

The fly ash handling systems include, but are not limited to, screw conveyors inside precipitator hoppers, rotary or double flap air lock valves, and dry drag type transfer conveyors.

1.12 Air Pollution Control Systems

Except as may be required under applicable law, the air pollution control systems at each facility shall consist of one electrostatic precipitator and one induced draft fan per combustion line.

1.12.1 Electrostatic Precipitators

Each combustion line shall be equipped with an electrostatic precipitator (ESP) including all appurtenances, structural supports, foundations, external and internal walkways, platforms access stairways, fly ash hoppers with discharge air lock valves, power and control wiring, and other accessories for a complete operation system.

Each ESP shall be a multi-field type with the output of each ESP's flowing into a single flue. The fields shall be sized adequately considering both the volume of gases and amount of excess air. The temperature of flue gases entering the ESP must be below 600°F and at least 40°F above the dew point temperature.

The U.S. Environmental Protection Agency's (USEPA) best available control technology (B.A.C.T.) shall define the minimum efficiency of the ESP's. The Contractor shall guarantee ESP performance. For the purpose of proposal submission, Proposers shall assume that the ESP outlet gases shall not exceed 0.03 grams per cubic foot of air. The actual required removal rate shall be determined during the permit negotiation process with the appropriate regulatory agencies.

Each ESP design submitted shall have been successfully operated in a facility firing Processable Waste for a minimum of three years. The proposed ESP shall not have been scaled up more than 25 percent over previous installation.

Casing and hoppers of each ESP shall be enclosed with weather resistant materials.

ESP structural design shall be based on all applicable codes as to dead, live, wind and seismic loads, using all external structural members, rigid frames, etc. Internal bracing exposed to the gas flow is not allowed. All design, fabrication and installation shall be in accordance with all applicable design codes and standards.

ESP internal walkways shall be provided at the inlet and outlet nozzles and between fields.

All ESP induction motors shall be extra severe duty high efficiency type, with a minimum guaranteed efficiency value which shall be confirmed by NEMA test standard MG-1-12.53a, (IEEE test procedure 112. Method B) using accuracy improvement by segregated loss determination including stray load loss measurement. All motors shall be labeled with the NEMA efficiency.

All ESP steel casing in contact with the flue gas shall be of ASTM A 242 steel; external structural members shall be ASTM A36 steel.

ESP gas distribution shall be accomplished via a low velocity, multiple vane system or a perforated plate system. It should be noted that as part of the contractual requirements of the selected Contractor, model studies of geometrically similar units shall be submitted for evaluation.

ESP collection systems shall consist of formed rolled ASTM A242 sheet of manufacturer's standard design.

ESP collecting surface rapping shall be by shaft-driven rotary hammers. Solenoid impact or vibration rapping is not acceptable.

ESP high voltage systems shall have star shaped, spiked stainless steel electrodes, rigid mast mounted; and high alumina refractory type insulators. Weighted wire systems will not be acceptable.

ESP discharge electrode rapping shall be accomplished by shaft mounted rotary hammers; solenoid impact or vibrating rapping is not acceptable.

ESP electrical systems shall be in accordance with ASA, AIEE, MENA and National Electrical Code requirements, designed by manufacturer. All operational functions controlled remotely from central control room. High voltage field control panel shall include all solid state, full wave bridge, thyristor type regulated D.C. supply with protective reactances. Saturable reactor systems are not acceptable. Key-type safety interlocks with sequential key arrangements shall be included on all precipitator access doors, rectifier enclosure access doors, high tension switching, and control units circuit breakers.

Minimum ESP remote control functions shall include:

- Transformer overload alarm.

- Precipitator failure alarm, if field ceases to operate, or if a long-term precipitator under voltage condition exists, while precipitator control is in on position.
- Isolated contact for precipitator field.
- Remote on-off switching.
- Hopper and insulator heaters failure alarm.
- Rapper start-stop-failure alarms.
- Flyash conveyor start-stop failure alarms.
- Flyash discharge air lock valves start-stop failure alarms.

ESP insulation (nozzles, sides, roof and hoppers) shall be mineral wool block or fiberglass blanket, applied directly onto the precipitator casing. Stiffeners and other structural members attached to the casing shall be wrapped with an insulating blanket.

ESP lagging shall be aluminum panels, except for the roof of the precipitator. Roof insulation shall be protected by purlins and metal panels which shall be designed for appropriate loads.

ESP flyash hopper heaters shall be the resistance type extending two thirds of the ash hopper height from the bottom of the hopper (to prevent blockage).

1.12.2 Induced Draft Fan Systems

Each furnace-boiler shall be equipped with an induced draft fan, an induced draft fan drive, an induced fan inlet damper, and appropriate breechings.

Induced Draft Fans: Induced draft fans shall be centrifugal, backward curved inclined blade, treated-radial tip type, designed for continuous operation at 600°F, in a dusty environment.

The fans shall conform to the following minimum requirements:

- o Fan speed not to exceed 750 RPM.
- o Equipped with access doors.
- o Insulation and lagging in accordance with that required for the ESP's.
- o Test block capacity factor: 1.15.
- o If erected on an elevated structure, the I.D. fans shall be mounted on spring-loaded inertia bases.
- o Fan blades shall be lined to withstand corrosion.

Induced Draft Fan Drives: The induced draft fans shall be coupled to electric VARIABLE SPEED DRIVE SYSTEMS consisting of either direct current drive motors with AC/DC converter or AC variable speed motors and operator control stations, as required.

The drive HP shall be a minimum of 115 percent of the fan test block BHP. The control system shall include positive acceleration on demand and deceleration by inertia.

Induced Draft Fan Inlet Dampers: The induced draft (I.D.) fan inlet houses shall be fitted with parallel blade type inlet dampers designed and manufactured for 600°F continuous operation. The dampers shall conform to the following minimum requirements:

- o Blades - ASTM A242 steel plates, air foil type.
- o External blade linkages.
- o End shaft connection with a universal joint (rigid jack shaft coupling not acceptable).
- o Damper operators - Worm gear reducers with beveled gear attachments and AWWA limit stops.

Induced Draft Fan Breechings: All breechings shall be of ASTM A-242 steel plate, reinforced as required. I.D. fan inlet and outlet breechings shall be connected to the I.D. fans via flexible joints and supported independently of the I.D. fans housings.

Shaft extension shall be fitted with a manual handle and a locking arrangement.

All breechings shall be insulated and lagged in accordance with that required for the ESP's.

I.D. fan outlet breechings shall be designed to enter stack(s) at not less than a 45 degree angle.

1.12.3 Stacks

The height of stacks at both sites is to be limited to 200 feet above final grade elevations.

The stacks shall include access ladders, a test platform located at the point required by testing procedures, test ports, access doors at the base of the stack, lightning protection system, and obstruction warning light system. Structural designs shall take into consideration all dead, wind and seismic loads, and shall include natural frequency vibration analysis where applicable.

Heights of the stacks shall be based on draft considerations and residual pollutant dispersion analysis in accordance with latest USEPA regulations along with Federal Aviation Authority (FAA) requirements since the sites are near commercial airports.

The stacks shall have one flue per combustion line and shall include provisions for a possible additional line.

1.12.4 Opacity Meter

The Proposer shall provide continuous read out opacity meter(s) in accordance with USEPA 40 CFR, Part 60.

1.13 Turbine-Generator Sets

1.13.1 System Design

At each facility the turbine-generator set shall consist as a minimum of the following component items:

- Turbine
- Generator
- Cooling Systems
- Operating Controls

At each facility, the Contractor may provide one multiple stage turbine generator set sized at 100 percent of the maximum generation rate.

Proposers should be aware that the Florida Public Service Commission's proposal rules and regulations, for qualifying alternative energy generation facilities, does contain provisions for minimum on-line generating reliability. Consequently, the Proposer may wish to consider incorporating more than a single turbine generator set at each facility. Should a Proposer wish to consider two turbine generator sets at either, or both, facilities, the Proposer shall be aware that Florida Power and Light may have limitations on the minimum size turbine generator installed.

Design of the turbine-generator sets shall also take into consideration the installed capacity, the available power and the spinning reserve power of the turbines.

The turbine-generator sets shall be designed such that no loss of energy production, either thermal or electrical, occurs throughout the lifetime of each facility. Each facility shall be able to process Processable Waste at full capacity even during scheduled and unscheduled outages of the turbine-generator sets.

The spinning reserve power of the turbines shall be such that variations in the steam mass flow from the boilers can be accepted without overloading the turbines.

1.13.2 Turbines

The turbines shall be radiographically tested, magnetic particle inspected, and sonic tested, as outlined in the currently applicable ASTM specifications.

The turbines, which shall be rated in accordance with the requirements of these specifications, shall be directly connected to the generator and shall drive the generator described herein as an integrated unit.

The turbines shall be designed for continuous operation, even if pressure at the turbine main steam stop valve rises to, but does not exceed, 105 percent of turbines rated pressure.

1.13.3 Generators

The generators shall be alternating current synchronous generators rated in accordance with the requirements of these specifications and shall be directly connected to and driven by the turbines described herein.

The generators shall be of the nonsalient pole revolved field type.

The telephone influence factors of the generators shall be in accordance with the latest ANSI Standards.

The deviation factor of the open circuit terminal voltage wave of the generators shall not exceed ten percent (as defined by ANSI standards.

The generator armatures shall be capable of operating at 130 percent of rated armature current for at least one minute, starting from stabilized temperatures at rated conditions.

The generator field windings shall be capable of operating at a field voltage of 125 percent of rated load field voltage for at least one minute starting from stabilized temperatures at rated conditions.

The generator will be capable of withstanding, without injury, the thermal effects of unbalanced faults at the generator terminals, including the decaying effects of field current (where protection is provided by causing field current reduction, such as with a field breaker or equivalent) and the DC component of the stator current, for times up to 120 seconds, provided the integrated product (It) of generator negative phase sequence current (I) and time (t) does not exceed 30 seconds.

The generator shall be capable of withstanding, without mechanical injury, and type of short circuit at its terminals for times not exceeding the short time thermal capabilities, when operating at rated KVA and power factor and five percent overvoltage, provided the maximum phase current is limited by external means to a value which does not exceed the maximum phase current obtained from the three-phase fault. In the case of stator windings, the criterion for no injury is that the windings will satisfactorily withstand a normal maintenance high-potential test. There will also be no visible abnormal deformation or damage to the winding coils and connections resulting from this test.

The generator shall be suitable, for operation at rated KVA, power factor, and frequency at any voltage not more than five percent above or below rated voltage, but not necessarily in accordance with the standards of performance established for operation at normal rating.

The generator shall be capable of operating continuously at full rated load under usual service conditions. The total temperatures as determined by any of the methods given in ANSI standards shall not exceed 110°C for the stator coils and 125°C for the field when operating at full load or below.

1.13.4 Cooling Systems

General: The following information pertaining to cooling systems is included to provide Proposers with the appropriate systems and project site constraints that may impact upon the actual implementation of a cooling system at the selected sites. The cooling method at each facility may eventually be:

- o Once through cooling (surface condenser).

- Evaporative cooling (evaporative cooling tower).
- Air cooling (air cooled condenser).

The final determination of the actual cooling system that will be utilized will be made prior to the approval of the final Contract Agreement.

For the purposes of this proposal submission, however, proposals shall be based upon the utilization of air cooled systems at both the Southern and Northern facilities.

At each facility the steam turbine(s) condenser(s) shall be designed to meet maximum boiler ASHRAE output without any steam being extracted for process, for the hottest day in the year, as per the Florida Weather Bureau, for the Broward County area.

The Proposer shall provide cooling systems sized to condense the exhaust steam for the turbine(s) assuming all boilers are in operation. Reducers and coolers of steam pressure shall be installed so that the facility can also bypass the turbine(s) and condense the total output of all boilers under maximum steam generation. Sustained venting of steam shall be avoided. The condensing system shall be valved and piped to increase operation and maintenance flexibility.

The following sections provide information to acquaint Proposers with the conditions that may impact on the final selection of the cooling systems at each of the selected sites.

Northern Facility (Copans Road Site): Contractors should be aware that the North Broward Regional Wastewater Treatment Plant lies just to the east of site selected for the Northern Resource Recovery Facility. The following information is provided for the period of August, 1982 through May 1983, on effluent from this facility.

	Min.	Max.
Daily Flow (MGD)	-	64.21
Minimum Hourly Flow(1)	10.0	-
Chlorine Residual (ppm)	0.5	2.4
BOD (mg/l)	2.0	13.0
TSS (mg/l)	3.0	22.0
pH	6.7	7.4
Fecal Coliform	<10.0	160.0
Temperature (°F)	78.0	86.0

(1) MGD basis occurred in August, 1982.

The effluent from this facility is currently discharged through an ocean out-fall with a maximum temperature discharge limitation of 97°F.

For eventual consideration of evaporative cooling at this site, the sources of water are limited to County water, as supplied by the County System 1-A plant, ground water, or wastewater treatment plant effluent (provided additional treatment is utilized to enable the acquisition of all necessary permits and approvals. With respect to County water, average annual water quality values are presented in Table A-3 of this Appendix. The Contractor will be responsible for determing makeup water requirements and County water availability to satisfy such requirements. With respect to utilization of groundwater, Appendix B, Environmental Specifications contains data regarding the underlying aquifers in this area.

Southern Facility (Route 441 Site): Steam pluming is of major concern at this site due to the proximity of Fort Lauderdale International Airport. Consequently, the eventual consideration of evaporative cooling tower(s) at this site, such towers would be limited to a wet-dry type to eliminate visible plume formation which would occur under certain wet bulb and relative humidity conditions.

City and County water (refer to Tables A-1 and A-3) or ground water may be considered for evaporative cooling use. As in the case for the Northern Facility, the Contractor shall be responsible for determining make-up water requirements and city water availability to satisfy such requirements.

Summary: THE DATA PRESENTED ABOVE REGARDING COOLING SYSTEMS IS PROVIDED FOR INFORMATIONAL PURPOSES AND FOR FUTURE REFERENCE ONLY. ALL PROPOSERS ARE REQUIRED TO BASE THEIR PROPOSALS ON AN AIR COOLED SYSTEMS AT BOTH FACILITIES FOR COMPARISON PURPOSES. THE ACTUAL COOLING SYSTEMS UTILIZED AT THE SELECTED SITES WILL BE DETERMINED DURING CONTRACT NEGOTIATIONS.

1.14 Process Control Systems

1.14.1 Local Automatic Control Systems

At each facility these systems shall provide for automatic shutdown of certain critical operations in the processes. This shall include, but not be limited to:

- Turbine Generator(s)
- Electrostatic Precipitators
- Conveyors
- Induced Draft Fans
- Pumps
- Stokers

These local control systems shall identify their actions to the remote central control systems.

1.14.2 Remote Automatic Control Systems

These on-line, real time systems shall provide automatic operation, control monitoring and data trending and logging of all plant process from the Central Control Room (CCR) of each facility, by means of a computer based central processing units (CPU).

The CPU's shall continually monitor the parameters of all the plant's process systems. The monitored data shall be used by the CPU's to determine whether the process lines are operating correctly, to identify any alarm conditions to the CCR operator that arise, and to generate operating and management reports.

The CPU's shall automatically control the operations of all process line component systems. Such control shall be in conjunction with any local control systems specified elsewhere in the RFP.

At each facility the systems shall provide to the CCR operators an interactive control station from which the operators shall institute process system startups and shutdowns, and affect modifications to all operating parameter setpoints.

The systems shall automatically optimize the operation of each process line by the proper coordination of the line's component systems, including, but not limited to: furnace grate speed control, under and over fire air feed control, temperature control, and boiler feed water control systems to provide maximum efficiency in steam generation.

The ratio of under and over fire air shall be automatically adjusted to compensate for the Processable Waste's moisture content so that a selected furnace temperature is maintained and complete burnout is obtained. The Processable Waste feed rate, grate speed and combustion air volume shall be adjusted to maintain optimum steam generation and complete burn-out.

The CPU's shall provide data logging and trending of all process parameters, including operator inputs to the system.

The systems shall be computer based and shall have a minimum of two CRT/keyboard operator stations and one printer for logging at each facility.

The mainframe processor (CPU) shall have sufficient memory capacity to contain all software operating systems and shall use, and be furnished with, mass storage devices of the rigid disk type for maintaining event data files, etc. Two magnetic tape drives shall also be furnished with each CPU and used for recording event data for off-line processing. Each CPU shall have a real time clock.

The CPU's shall perform an auto restart after a power failure and restoration of power. Floppy disks may be used for system initialization and restarts requiring software reloads. However, Floppy disks shall not be used for any continuous system function.

At each facility a priority software interrupt system shall be furnished and all high priority alarms shall be individually hand wired into this sytem, e.g., high steam pressure, malfunction of boiler feed water pump, etc. The CPU's shall instantly respond to all priority interrupts received and indicate appropriate action.

In the event of system malfunctions and/or alarms, the CPU's shall identify the event to the operator in fully description English text and shall also "prompt" the operator with a complete list of the actions to be taken in response to the specific event.

The CPU's shall monitor all process operating parameters and shall maintain and store the same for a minimum period of 30 calendar days.

The CCR operators shall have access to this stored data and be provided with requested hardcopy printouts of a specified parameter over a specified period of time.

1.14.3 Local Manual Control Systems

At each facility these systems shall provide manual on/off and lock-out controls for all moving equipment in the processing systems, i.e., electric motors, hydraulic or steam driven devices, etc. The manual control systems are required specifically for the safe performance of maintenance operations and for equipment testing and startup operations. The remote control systems shall monitor the status of these local manual controls and take appropriate action in response to the status indicated.

1.14.4 Remote Manual Control Systems

At each facility these systems shall provide for the manual operation of the plant's process lines from the plant's central control room. The systems shall be operated from a control and information display board which shall contain start/stop controls for all process operations, instrumentation indication of all critical and necessary parameters associated with the process operations, and alarm and status indication lights for all process operations. The alarm lights shall be provided in addition to an audible indication of a change in their status, to be sounded both in the central control room (CCR) and the plant floor, to cover the event of the CCR being unoccupied. This audible indication to the plant floor areas shall be a unique sound unlike any other audible indications in the facility.

The control/display boards shall be laid-out as a semi-graphic representation of the plant and its process lines. There shall be a fixed graphic display of each plant process line, from chute to stack, and all controls, alarms and instrumentation shall be located and identified such that they are immediately identifiable with their associated process components. A separate section of the control display (C/D) board shall be utilized for the steam and electricity distribution systems.

1.14.5 Control System Priorities

At each facility the local manual "on-off-auto" type controls shall take precedence over all types of controls. The next highest priority shall be that of the local automatic controls. The next priority shall be to the remote manual control board and lastly to the remote automatic computer controls.

1.14.6 System Requirements

All systems shall be comprised of the latest generation of electronic components and the computer software programs shall be written in a high order language.

Maintenance forces for the electronic systems selected shall be available in the Broward County area in sufficient quantity to guarantee 24-hour on-site response to maintenance calls.

1.14.7 Uninterruptible Power Supplies

At each facility an uninterruptible power supply system (UPS) shall be provided to supply power in an emergency to the remote automatic control system and to other facility equipment requiring UPS for its protection in an emergency.

This UPS shall include a converter and a battery storage system. The converter shall have, but not be limited to, a separate isolation step-down transformer, a solid state inverter bypass switch, an automatic transfer switch, input and output circuit breakers, meters, pilot status lights, low alarm, output frequency meter, manual TS control and fault alarm.

The battery storage system shall include lead-calcium batteries, tiered storage racks with interconnecting metal straps, and battery charger. The capacity of the UPS systems shall be twelve hours and shall be rated at not less than 50 KVA for the northern facility and 100 KVA for the southern facility, 120 volt, single phase outlet with one-hour battery reserve power.

1.14.8 Process Alarms

At each facility alarm annunciators shall be provided to alert the control room operators or other operators/attendants to abnormal process conditions of particular importance. These alarm systems will sound until acknowledged by the operators, and the status lights for the alarms will continue to be "on" until the abnormal conditions are attended to.

The various alarms shall be organized on annunciator panels located in the central control room. In addition, duplicate alarms shall be located at local alarm stations, such as the stoker panels, the turbine-generator rooms, the water treatment system rooms and the precipitator control consoles.

1.14.9 HVAC

All central computer system areas and all UPS battery storage areas shall be provided with the special air conditioning required for each area's proper operation.

Each battery storage area shall have a continuous exhaust of air to prevent hydrogen buildup and the area's temperature shall not exceed 85°F to prevent shortening of the batteries' life.

Each computer room shall have a floating floor which shall be utilized for all cable entry to the equipment and for forced air ventilation of the equipment cabinets. The ambient temperature in each room shall be maintained at 70°F, but in no case shall the temperature within any equipment cabinet be allowed to exceed 85°F.

1.15 Facility Security and Communication Systems

1.15.1 Facility Security

The Contractor shall be solely responsible for providing adequate security at each site, both during construction and operation of the facility.

Security during operation of the facility may include personnel, video, lighting, as well as electronic alarms. One, or a combination, of the methods shall be instituted at the Contractor's discretion.

1.15.2 Communications

The communications systems shall include the following services at each facility: telephone, intercom, public address, and two-way radio.

1.15.3 Security Lighting

Security lighting shall be provided on the exteriors of all facility buildings, in the vehicle parking lot(s), and on the entire perimeter fence. The type of light fixtures and the footcandle level of the illumination shall, as a minimum, be high pressure sodium and 2.5 foot candles.

SECTION 2

LANDFILL TECHNICAL SPECIFICATIONS

2.1 Introduction

As with the preceding technical specifications for resource recovery facilities, the purpose of these landfill technical specifications is to set minimum guidelines and functional design requirements to insure comparable proposals of uniform quality.

In addition, the County has initiated the permit application process with the appropriate government agencies, for the Residue/Unprocessable Waste landfills. As part of this activity, the County has and will continue to develop permit submittals containing landfill plans. The Proposals developed by the Proposers must conform to the plans and requirements contained in these permit submittals. As an example, a landfill liner, leachate control system and stormwater drainage system will be required at each of the landfills as part of the permit conditions. As a result, these items must be treated as required in each Proposal.

The Proposer is not limited to these minimum requirements and guidelines, however, should the Proposer desire to change the functional design requirements described herein, the Proposer shall utilize Proposal Form 2.2 of the RFP to describe the change.

The Proposer shall provide for the design, construction and operation of separate Residue/Unprocessable Waste landfills, together with the associated landfill facilities at the northern and southern resource recovery sites. Descriptions of these sites are provided in section 4.7 of the RFP. More specifically, development of these landfills shall include but not be limited to the following at each landfill:

1. Construction and maintenance of access roadways and parking areas.

2. Furnishing, installation and maintenance of a site security system.

3. Furnishing, installation, operation and maintenance of a truck weighing scale.

4. Furnishing, construction and maintenance of a scale building.

5. Furnishing, construction and maintenance of an equipment shed.

6. Furnishing, installation, and maintenance of landfill liners.

7. Furnishing, construction, operation and maintenance of leachate collection and disposal systems.

8. Construction and maintenance of storm water drainage systems.

9. Clearing and grubbing of trees, brush, shrubs, and stumps within the limits of the site.

10. All excavating, backfilling and disposing of all materials, including unsuitable muck material, encountered at the site as required for the purpose of constructing structures, conduits, pipelines, roads, grading and other facilities required to complete development of the site.

11. Provisions for water, sewage, fire protection, and other utilities.

12. Furnishing, installation, operation and maintenance of a gas control system.

13. Furnishing, installation, and maintenance of groundwater monitoring wells.

14. Placement and compaction of select fill, as required, to increase site elevations to 100 year flood elevations prior to placement of solid waste.

In all cases, the above described work, and any other work required to complete the design, construction and operation of the Residue/Unprocessable Waste landfills, shall be in compliance with all applicable federal, state, county and local rules and regulations.

In addition to the development and construction of the Residue/Unprocessable Waste landfills, the Proposer shall be responsible for the operation, maintenance and final closure of these landfills.

2.2 General Design and Construction Requirements

In addition to the specific design requirements described in the site work section, the Contractor shall meet the following general design requirements:

- The bottom of the landfills must be at least 5 feet above the groundwater table. To provide a suitable base for constructing the landfills it will be necessary to remove all unsuitable materials and to place clean fill on the site to establish the 5 foot separation of the groundwater table and the landfill bottom. If excavation uncovers an unexpected water table that cannot be lowered the excavated area must be backfilled to a point that will provide the necessary 5 foot separation.

- Select fill must be placed and compacted wherever necessary to increase grade elevations to 100 year flood elevations. This will insure that solid waste will not be placed in future flood waters.

- The top slope of completed landfill sections must be maintained at 2 percent or greater for drainage and the slopes at the sides of the fill should not be steeper than 3 horizontal to 1 vertical.

- All materials and equipment used in the construction of the landfill should be handled, stored and installed in accordance with the manufacturer's recommendations.

- All concrete structures, including drainage ditches, shall be constructed on a 12-inch layer of clean, fill. Backfill structures shall be backfilled with 12-inch thick layer of clean fill all around and tightly compacted.

- Erosion control measures such as straw bales, silt fences and temporary seeding must be utilized to keep erosion of soil to a minimum.

- A sufficient number of ground water monitoring wells shall be provided to determine ground water flow direction, background ground water quality and subsurface geology, as required by the appropriate regulatory agency(ies).

- A landfill liner system shall be installed and maintained to contain infiltrated rainfall in accordance with the requirements of the Florida Department of Environmental Regulation (DER) and Broward County Environmental Quality Control Board (BCEQCB).

- A leachate collection system shall be installed, operated and maintained to collect and remove leachate from the landfill in accordance with the requirements of the Florida DER and BCEQCB.

- A storm water drainage system shall be installed, operated and maintained in accordance with the requirements of the South Florida Water Management District.

Conceptual layouts of the northern and southern landfills are included in the RFP as Figures 2 and 3, respectively.

2.3 General Operational Requirements

As part of the operational requirements, the Contractor shall develop operational procedure and maintenance manuals, which shall include, but not be limited to, the following items:

- Operation hours;
- Weighing procedures;
- Vehicle flow and unloading;
- Waste handling procedures;
- Placement of cover;
- Maintenance procedures;
- Operating procedures for various weather conditions;

- Fire prevention procedures; and
- Salvage and screening policy and procedures.

In addition to the development of operations and maintenance manuals, the general operational requirements for the Residue/Unprocessable Waste landfills include:

- All of the permanent facilities that will impact on the proposed landfill must be constructed prior to placement of waste in a new area. This includes such items as storm drainage lines and ditches, liner and leachate collection system, monitoring wells, haul roads and gas vents.
- Temporary measures that must be pursued on a continuous basis include temporary surface water diversion ditches, erosion control measures, and fencing to control blowing paper.
- The solid waste shall be covered according to the requirements of the applicable regulatory agency(ies). Final cover, however, shall consist of a layer of impervious material having a permeability of 10^{-7} cm/sec or less, topped with sufficient topsoil to support the growth of vegetative cover. Vegetative cover must then be established to prevent erosion.
- Burning of waste shall not be allowable and hazardous waste shall not be acceptable for disposal at the sites.
- A minimum 100 foot separation distance shall be maintained between fill areas and property boundaries. (Zoning Ordinances and permit requirements may necessitate larger separation distances).
- Initially, gas monitoring wells shall be tested once a month. If explosive limits of gas are detected, then a more extensive monitoring program should be developed. This more extensive monitoring program could involve additional monitoring wells as well as mitigating measures to stop the migration of gas.
- Ground water samples shall be taken in accordance with regulatory requirements and guidelines and shall be tested for those parameters required by the applicable regulatory agencies.
- After an area of the landfill is completed and final cover is applied, regular checks of the area will be

made to determine if any erosion is taking place. Any eroded areas will be filled and a dense stand of grass established. An active ground water and gas monitoring program meeting the requirements of the Florida Department of Environmental Regulation will be carried out to make sure the landfill does not have an adverse effect on the environment.

2.4 Environmental

The Proposer shall assume and provide that, the design, construction, and operation of the Residue/Unprocessable Waste landfills shall comply with all applicable federal, state, county and local environmental regulations and standards in effect as of the proposal submission due date, unless otherwise advised in writing by the County. These environmental requirements will cover all air quality, water quality, traffic, noise, odor/vector control, residue, and community impacts. In particular, the design, construction and operation of the Residue/Unprocessable Waste landfills shall at all times be in compliance with the rules and regulations of the Florida Department of Environmental Regulation, specifically Chapter 17-7 Resource Recovery and Management; Part I: Solid Waste Facilities. Specific mitigating measures will be necessary at the southern site to minimize the environmental input on the South New River Canal.

The Proposer shall itemize the measures by which all adverse environmental impacts will be mitigated including design features, construction procedures, operating procedures, and control hardware.

Attendance and participation at meetings and hearings will also be required of the Proposer and others retained by the Proposer in connection with the permit approval, and certification process. A listing of the environmental permits and regulations that may be applicable to these landfills is provided in Appendix B.

Information pertaining to the Proposer's Residue/Unprocessable Waste landfills is to be provided in the proposal on Form 2.4 Technical Data; Section 2.4.6 Residue/Unprocessable Waste Landfills. Specifically this section requests information concerning the following:

- Development plan.
- Type of security system.
- Operations plan.
- Liner system.
- Leachate system.
- Closure cover.

The Proposer may provide additional information by attaching supplemental sheets to the proposal.

The following sections are intended to provide an overview of the environmental requirements for the residue/unprocessable waste landfills. These requirements include but are not limited to:

2.4.1. Design and Construction Requirements

During construction of the landfills, the Contractor will be required to:

- Control or prevent fugitive dust emissions.
- Prevent the depositing of dirt and construction debris on neighboring streets and properties.
- Provide for control of soil erosion and sedimentation of existing water courses.
- Provide appropriate disposal for any water removed through dewatering.

2.4.2. Operations Requirements

During operation of the landfills, the Contractor will be required to:

- Train special environmental personnel.
- Prepare operational procedure and maintenance manuals.
- Develop practices to define the nature and quality of waste input to prevent the processing of obnoxious, undesirable, and hazardous material at the landfills.
- Prevent dirt and debris from being deposited on neighboring streets.
- No solid waste shall be disposed of:
  - within 200 feet of any natural or artificial body of water, except canals used to lower site water tables or bodies of water, contained completely within the site, which do not discharge from the site.
  - within 10,000 feet of the closest point of any runway at any airport licensed by the State of Florida, owned or operated by the United State, or subject to regulation by the Federal Aviation Administration which may be used by turbo-jet aircraft; or within 5,000 feet of any runway at any such airport used only by piston engine type aircraft unless it has been determined by the Federal Aviation Administration, or other appropriate federal or state agency charged with preventing airport hazards, that the proposed solid waste facility poses no safety hazard to aircraft in the vicinity.

2.4.3 Water Quality Requirements

No substance shall be discharged into the surface waters, groundwaters, storm or sanitary sewer system without the approval of the applicable agency(ies) regulating that discharge.

Proposers shall provide sufficient information and data on the proposed landfills including any necessary leachate pretreatment process, to show how compliance with these regulations and standards would be achieved.

2.4.4 Noise Impact Requirements

The proposal shall indicate, among other things, the methods to be used to safeguard both people working at the landfills and in neighboring areas from exposure to noise levels, greater than allowable thresholds, during both construction and operation.

The design and selection of equipment and construction materials should be made with consideration to the minimizing of noise generation within the site property lines and the transmission of noise beyond the property lines, and shall incorporate any design or operation measures requested by the County. The prevention of community nuisances due to excessive noise during construction and operation is extremely important to assure that the landfills are "good neighbors".

2.4.5 Odor/Vector Control Requirements

The Proposer shall provide sufficient controls to insure that the landfills will not constitute a hazard to public health, safety, or property both on-site, and in neighboring communities.

The design of the Residue/Unprocessable Waste landfills and associated facilities shall include all necessary provisions as required by Federal, State and local laws and regulations to eliminate any potential problems with odor or vector control.

APPENDIX B

ENVIRONMENTAL SPECIFICATIONS

APPENDIX B

ENVIRONMENTAL SPECIFICATIONS

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1.1 Applicable Codes

The Project shall be designed, constructed, and operated in accordance with the latest editions, including all addenda, of the applicable codes, legislation, regulations and standards listed in this section. This list is to be used as a guide and is not necessarily inclusive of all cognizant organizations and their codes and regulations. The Contractor shall meet all applicable codes and regulations, whether or not listed herein. The Project shall be designed, constructed, and operated to insure compliance with environmental laws and regulations of all federal, state, county and local governments having appropriate jurisdiction. Where portions of any such requirements are in conflict, the most stringent shall govern.

The Contractor shall obtain all permits and licenses necessary for the construction and operation of the Project. To expedite the Project, the County has already begun the application process. During contract negotiation, the Proposers will be responsible for monitoring this process and assisting the County. Upon execution of a contract, the Contractor will become responsible for attaining these permits and will adopt the County's prior submissions as its own.

1.1.1 Federal Codes

Prevention of Significant Deterioration (PSD), (Clean Air Act Amendments of 1977 PL 95-95, 127(a), 91 Stat. 731 Sections 160-169) 40 CFR Parts 50, 51, 52, 60, 61

Dredge and Fill Permit, (Clean Water Act Amendments of 1977 and 1981 PL 95-217 and 97-117 86 Stat. 816, 33 USC 466 et seq.) 40 CFR Part 230

National Environmental Policy Act (NEPA), (PL 91-190)

U.S. Department of Transportation, Federal Aviation Administration (FAA) Regulations (Part 77 - Objects Affecting Navigable Airspace)

National Pollutant Discharge Elimination System (Clean Water Act Amendments of 1977 and 1981 PL 95-217 and 97-117, 33 USC 466 et seq.) 40 CFR Parts 121-125

Resource Conservation and Recovery Act of 1976 as Amended (RCRA) (PL 94-580 and 96-510, 90 Stat. 95, 42 USC 6901 et seq.) 40 CFR Parts 260-265

Standard Performance for New Stationary Sources (USEPA) 40 CFE, Part 60, Proposed Revisions to Subpart D, dated June 19, 1984.

1.1.2 State of Florida Codes

Development of Regional Impact Regulations (Florida Environmental Land and Water Management Act of 1972 ss. 380.012-380.10 FS, Chapters 9B-16.16,, 22F-1, and 22F-2 FAC)

State Air Pollution Control Permit (Florida Air and Water Pollution Control Act ss. 403.011-403.4153 FS, Chapters 17-2 and 17-4 FAC)
Sections 17-2.03, 17-2.04, 17-2.05, 17-4.05, 17-4.21, 17-4.22, 17-4.23

State Solid Waste Facility Permit (Florida Air and Water Pollution Control Act ss. 403-011-403 4153 FS, Chapters 17-4 and 17-7 FAC)
Sections 17-4.05, 17-4.28, 17-4.22, 17-7.01 17-7.11

State Dredge and Fill Permit (Florida Air and Water Pollution Control Act ss. 403.011 - 403.4153 FS, Chapters 17-3 and 17-4 FAC)
Sections 17-4.05, 17-4.28, 17-4.24, 17-4.31

South Florida Water Management District Permit (Florida Water Resources Act of 1972, ss. 373 FS, Chapter 40E FAC)
Sections 40E-1.6, 40E-2, 40E-20, 40E-40

Electrical Power Plant Siting Regulations (The Florida Electric Power Plant Siting Act ss. 403.501-403.517 FS, Chapter 17-17 FAC)
Section 17-17.04

State Water Pollution Control Permit (Florida Air and Water Pollution Control Act ss. 403.011-403.4153 FS, Chapters 17-3 and 17-4
Sections 17-3.051, 17-3.061, 17-3.121, 17-4.05, 17-4.21, 17-4.22, 17-4.24, 17-4.244, 17-4.245

State Underground Injection Permit (Florida Air and Water Pollution Control Act ss. 403.011-403.4153 FS. Chapters 17-3, 17-4, 17-28 FAC)
Sections 17-3.051, 17-3.071, 17-3.151, 17-4.21, 17-4.22, 17-4.24, 17-28 Parts I, II, III

1.1.3 Broward County Codes

Construction/Operation Licenses for Air Pollution Sources (Broward County Environmental Quality Control Act, Chapters 27-3 and 27-4 BCC)
Sections 27-3.04, 27-3.05, 27-3.08, 27-3.31, 27-3.32, 27-4.03, 27-4.04

Construction/Operation Licenses for Water Pollution Sources (Broward County Environmental Quality Control Act, Chapters 27-3 and 27-5 BCC)
Sections 27-3.04, 27-3.05, 27-3.08, 27-3.21, 27-3.25, 27-5.03, 27-5.04, 27-5.06, 27-5.07, 27-5.08

Construction/Operation Licenses for Solid Waste Pollution Sources (Broward County Environmental Quality Control Act, Chapters 27-3 and 27-6 BCC)
Sections 27-3.04, 27-3.05, 27-3.08, 27-3.40, 27-3.41, 27-3.42, 27-3.43, 27-3.44, 27-6.03, 27-6.04

Construction/Operation Licenses for Noise Sources
(Broward County Environmental Quality Control Act, Chapters 27-3 and 27-7 BCC)
Sections 27-3.04, 27-3.05, 27-3.08, 27-7.04, 27-7.05, 27-7.07

1.2 Emission of Air Pollutants

Contractors proposing a technology that results in the release of pollutants to the atmosphere are herein notified that Federal, State and County laws regulate such emissions. The following information, provided as guidance, outlines certain aspects of regulatory requirements that may be applicable to the Project. The vendors are herein notified that particulate matter emissions shall be controlled to .03 grains per dry standard cubic foot of exhaust gases or 0.1 lbs per million btu heat input, whichever is more restricted.

1.2.1 Air Pollutants Specifically Regulated

Broward County Code 27-4.04, FAC 17-2 and 17-4 and USEPA 40 CFR 50 have established ambient air quality standards for certain classes of air pollutants. The following list includes the classes governed by one or all of these regulations:

- Particulates
- Carbon Monoxide
- Sulfur Oxides
- Nitrogen Oxides
- Non-Methane Hydrocarbons
- Lead
- Photochemical Oxidants

1.2.2 Unregulated Air Pollutants

With respect to air pollutants not specifically regulated, Proposers are advised that during Broward County Environmental Quality Control Board (BCEQCB) review under Chapter 27-3 and 27-4, Florida Department of Environmental Regulation (DER) review under FAC 17-2 and 17-4 and the USEPA review under 40 CFR 52, the potential for emitting any of the following pollutants, for which no specific regulatory criteria exists, may be critically examined.

- Aluminum
- Antimony
- Arsenic
- Asbestos
- Bacteria & Viruses
- Hydrogen Chloride
- Manganese
- Mercury
- Nickel
- Polychlorinated Biphenyls

- Beryllium
- Cadmium
- Chlorinated Dibenzodioxins
- Chlorinated Dibenzofurans
- Chromium
- Copper
- Fluorides
- Polynuclear Aromatic Hydrocarbons
- Sodium
- Sulfuric Acid
- Tin
- Vinyl Chloride
- Zinc

1.2.3 Regulatory Program Requirements

The discharge of air pollutants from the proposed facilities is subject to BCEQCB, DER and USEPA regulation and approval. USEPA 40 CFR 52 regulates the increment of ambient air quality degradation allowed as a result of the operation of a new source. The final Prevention of Significant Deterioration (PSD) new source review, conducted by USEPA, may require that sophisticated, state-of-the-art modeling be undertaken in order to demonstrate that the Project will be in compliance with all ambient air quality standards, including available PSD increments. Sophisticated modeling may be necessary because of the proximity of other major sources to the site of the Project and possible complex wind flow fields and dispersion patterns. It is, therefore, recommended that the Contractor give serious consideration to a design which would optimize exit flow characteristics and stack height (not to exceed Good Engineering Practice) to maximize atmospheric dilution and dispersion of pollutants emitted.

1.2.4 Baseline or Background Ambient Air Quality

Federal, State and County ambient air quality standards are provided in Table B-1. Results of 1979-1980 ambient air monitoring at Broward County monitoring stations near the Copans Road and Route 441 sites are summarized in Table B-2.

1.3 Discharge of Water Effluent

The Project shall conform to all Federal, State and local requirements for the discharge of wastewater from the site.

The County has filed an application with the South Florida Water Management District in December 1983 for a Surface Water Management Permit at each project site. Agency review of these applications has been suspended until a Contractor is selected.

The County also filed an application for a Water Management Permit for each project site with the Broward County Water Management Division in December 1983. Division review of these applications also has been suspended until a Contractor is selected.

1.3.1 Cooling Water Discharges and Withdrawals

Based on the quality and quantity of available surface and ground waters and potential thermal reduction processes, there appear to be several feasible alternatives for withdrawing and discharging cooling water for the proposed resource recovery facilities:

- raw water supplied from the Floridan Aquifer for a once-through cooling system with subsequent injection into the Boulder Zone.
- make-up water supplied from the Biscayne Aquifer for an evaporative cooling tower with blowdown discharge injected into the Floridan Aquifer, the Boulder Zone, or surface waters.
- make-up water supplied from the South Fork of the New River for an evaporative cooling tower with blowdown discharge injected into the Floridan Aquifer, the Boulder Zone or surface waters.
- Discharges shall be free of any biologically toxic or hazardous substances which may result in an upset at the receiving sewage treatment plant.
- Discharges shall be free of any garbage that has not been shredded or otherwise processed.
- There shall be no discharges of storm water into sanitary sewers.

Criteria for discharges to storm sewers:

- No sewage, industrial waste, cooling water or other wastewater effluent shall be discharged into any sewer designated to carry storm water.

TABLE B-1

AMBIENT AIR QUALITY STANDARDS

Pollutant(1)	Federal Primary	Federal Secondary	State & County
Suspended Particulates			
Annual Geometric Mean	75	60	60
Maximum 24 hr concentration(2)	260	150	150
Sulfur Dioxide			
Annual Arithmetic Mean	80 (0.03 ppm)		60 (0.02 ppm)
Maximum 24 hr concentration(2)	365 (0.14 ppm)		260 (0.1 ppm)
Maximum 3 hr concentration		1,300 (0.5 ppm)	1,300 (0.5 ppm)
Carbon Monoxide			
Maximum 8 hr concentration(2)	10 (9 ppm)	Same as Federal Primary	Same as Federal Primary
Maximum 1 hr concentration	40 (35 ppm)		
Photo Chemical Oxidants			
Maximum 1 hr concentration(2)	240 (0.12 ppm)	160 (0.08 ppm)	Same as Federal Secondary
Nitrogen Dioxide			
Annual Arithmetic Mean	100 (0.05 ppm)	Same as Federal Primary	Same as Federal Primary
Hydrocarbons			
Maximum 3 hr concentration (6-9 a.m.)(2,3)	160 (0.24 ppm)		160 (0.24 ppm)
Lead			
Quarterly Arithmetic Mean	1.5	Same as Federal Primary	None Established

(1) All measurements are in ug/m^3 except CO which is mg/m^3.
(2) Concentration limits not to be exceeded more than once per year.
(3) Used as guide in devising plans to achieve oxidant standards.

TABLE B-2

BROWARD COUNTY ENVIRONMENTAL QUALITY CONTROL BOARD
1979-1980 AMBIENT AIR MONITORING DATA
(ug/m^3)[1]

	Station 2[2]	Station 3[3]	Station 8[4]	Station 10[5]	Station 12[6]	Station 13[7]
Nitrogen Dioxide	ND	ND	38.1	ND	24.0	ND
Sulfur Dioxide	ND	ND	BDL	ND	2.6	ND
Carbon Monoxide	ND	ND	ND	ND	2.4	
Total Suspended Particulates	46.0	43.0	40.0	46.1	44.2	ND

<u>Notes:</u>

1 All values are annual arithmetic means except for particulates which are annual geometric means; carbon monoxide expressed as parts per million (ppm)

2 Station 2 is 3.5 miles west of the Copans Road site.

3 Station 3 is 2.5 miles east of the Copans Road site.

4 Station 8 is 2.0 miles west of Route 441 site.

5 Station 10 is 4.5 miles southeast of Route 441 site.

6 Station 12 is 4.5 miles northeast of Route 441 site.

7 Station 13 is 1.5 miles north of Route 441 site.

ND - no data

BDL - below detectable limits

1.3.2 Discharge to Sanitary and Storm Sewers

The following criteria apply to any and all discharges from the proposed Project to the sanitary sewer system.

- Discharges shall be free of any benzene, gasoline, fuel oil or any other flammable or combustible materials.
- Discharges shall be free of any solids that may restrict or obstruct flow through the sanitary sewer system.
- The temperature of any discharge shall at no time exceed 150 degrees fahrenheit.
- Discharges shall at all times be free of any highly corrosive materials.
- At no time shall a discharge have a pH below 5.5 or above 9.5 units.

1.3.3 Regulatory Program Requirements

The discharge of cooling water effluent to surface or ground waters is regulated by the BCEQCB and DER, and effluent limitations determined by BCEQCB and DER must be met. To obtain a surface water discharge permit for cooling water, the potential impact of the thermal discharge on the receiving water temperature standard must be evaluated. The effects of any other discharge constituents on receiving waters must also be evaluated. For a ground water discharge by injection, an underground injection well permit must be obtained from DER. It must be demonstrated that the hydrogeologic environment is suitable for waste injection and will not endanger underground drinking water sources or modify ambient water quality in other overlying aquifers. Regional impacts may also have to be considered. A suitable confining zone, confirmed by testing, must exist above the injection zone. DER has also developed construction and operation requirements for injection wells in Chapter 17-28 FAC.

In addition to these permits, the South Florida Water Management District (SFWMD) regulates water withdrawal and artificial recharge of ground water in Broward County and the surrounding area. Industrial Water Use permits are granted contingent upon the demonstration that the withdrawal will not influence the inland movement of the salt water interface, affect potable water supplies or existing legal uses, or cause other impacts identified in SFWMD regulations and guidelines. For permitting purposes, ground-water recharge, through underground injection, is evaluated on a case-by-case basis, with the SFWMD and DER permitting reviews coordinated as one process.

1.3.4 Baseline or Background Ambient Water Quality

Water quality data for the South Fork of the New River, adjacent to the Route 441 site, over the period 1979 to 1980 is provided in Table B-3. There are no surface water monitoring stations in the vicinity of the Copans Road site. The Route 441 site lies in the western edge of the extensive coastal area subject to salt water intrusion. The Copans Road site is approximately three miles west of the affected coastal area. Ground water information for geologic formations underlying Broward County is summarized in Table B-4.

1.4 Dredge and Fill Activities

The filling in of regulated wetlands and dredging or filling projects in surface waters are regulated by Federal, State and County agencies through their permitting programs.

1.4.1 Regulatory Permit Requirements Route 441 Project Site

The U.S. Army Corps of Engineers (COE) and DER have determined that a portion of the Route 441 site is regulated wetlands. A permit is, therefore, required for facility construction in or affecting this area from both regulatory agnecies.

The County filed a joint application for a dredge and fill permit with both the COE and DER for this site in

TABLE B-3

BROWARD COUNTY ENVIRONMENTAL QUALITY CONTROL BOARD
1979-1980 AMBIENT SURFACE WATER MONITORING DATA*
S. Fork of New River near Route 441

	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.
BOD, mg/l	1.6	2.0	1.0	1.1	2.0	2.0	2.3	2.0	2.0	1.6	2.4
Dissolved Oxygen, mg/l	2.4	3.4	2.6	1.8	6.0	5.5	5.5	3.9	2.5	2.6	2.10
Nitrogen, mg/l	1.9	2.2	2.1	1.6	1.8	2.1	2.0	1.9	1.9	1.9	2.2
pH	7.6	7.6	7.4	7.5	7.7	7.9	7.6	7.6	7.7	7.6	7.6
Temperature, °F	81	77	66	72	68	79	77	82	86	86	86

*Average Monthly Values

November 1983. The County received a Letter of Intent to Permit from the COE in August 1984. COE permit issuance is conditioned upon the County obtaining a dredge and fill permit from DER. The COE is not requiring an Environmental Impact Analysis nor a public hearing for this permit application.

The County is anticipating a Letter of Intent to Permit from DER in September 1984. At a minimum, DER will require a public hearing.

Copans Road Project Site

The COE has determined that a dredge and fill permit is not required for the Copans Road Project Site (Appendix J). However, DER has determined that a portion of this site is regulated wetlands. The County, therefore, filed an application for a dredge and fill permit with DER in November 1983. The DER issued a Letter of Intent to Permit in June 1984. (Administrative Hearing comments).

TABLE B-4

PRELIMINARY GEOTECHNICAL INFORMATION SUBSURFACE STRATA OF BROWARD COUNTY

Generalized Formation Category	Base of Formation (Feet)	Permeability (Feet/Day)	Transmissivity (gpd/ft)	Temperature (Deg. F)	Salinity (mg/1)	Total Hardness as $CaCO_3$ (mg/1)	TDS (mg/1)	Porosity (%)	Geological Description
Biscayne Aquifer	160			66-68					Fossiliferous limestone
Hawthorn Formation	890			67					Marl & limestone with chert lenses.
Floridan Aquifer	1,860		88,000 to 250,000	67-68	6,060 - 19,150	3,350 - 10,600	6,834 - 24,036	Varies extensively	Crystalline limestone to biocritic limestone
Confining Bed	2,000			67-68				30-40	Biomicritic limestone with layers of silty marly material.
Saline Water Bearing Zone	2,100			67-68					Dolomite interbedded with limestone with cavities
Confining Bed	2,570	0.0218		67-63				28	Soft, silty, marly biomicritic limestone
Saline Water Bearing Zone	2,690			63-49	36,100	6,200	43,400		Limestone and dolomite with producing zones
Leaky Confining Bed	2,930	0.0821 to 0.439						31-38	Limestone with small amounts of dolomite
Boulder Zone			22,000,000 45,000,000(1)	51 63(1)	36,850	6,400	45,000		Dense, hard dolomite. Massive rock with numerous vugs, fractures and cavities

*Information derived from Ft. Lauderdale Test Injection Well except where noted.

(1) West Palm Beach Wells

1.5 Residue (Ash) Generation and Disposal

The quality and quantity of residue (solid waste) to be disposed of in a sanitary landfill may be reviewed in accordance with 40 CFR 241 and may be further regulated by 40 CFR 260-265. Landfill disposal of residue is also subject to BCEQCB and DER regulatory approval. This residue shall contain less than 4.0 percent combustibles and shall contain less than 0.2 percent (dry weight basis) of putrescible matter.

1.5.1 Residue Quality and Regulatory Program Requirements

Fly ash from air pollution control equipment and boiler bottom ash may both contain heavy metals. Previous studies have indicated that boiler bottom ash metal concentrations can be expected to be less than RCRA defined hazardous waste levels; however, fly ash analyses have indicated that metal levels may exceed RCRA defined hazardous waste levels.

The Contractor may be required to characterize the ash residue as hazardous or non-hazardous based on RCRA criteria in 40 CFR Part 261. The most critical criterion will be the toxicity of the residue, as determined by an EP toxicity test. If the residue is found to be non-hazardous, State sanitary landfill criteria and County regulations will apply to the disposal of the residue. Procedures provided in 40 CFR 241, Guidelines for Land Disposal of Solid Wastes, should also be considered. If the residue is determined to be hazardous, provisions found in Chapter 17-7 FAC and in RCRA regulations will apply to the generation, transport and disposal of the hazardous residue. The Contractor is encouraged to consider process alternatives, such as mechanical mixing of boiler bottom and air pollution control device ash as an integral part of the process, which may result in the formation of non-hazardous residuals.

1.6 Environmental Testing

During trial operation of the constructed Project, the Contractor will be required to conduct tests to verify compliance with existing regulatory requirements and permit conditions.

1.7 Environmental Performance Guarantees

The Contractor shall guarantee that during construction, start-up, testing, and operation that all Federal, State, County, or local environmental laws and regulations in effect as of June 30, 1983, or later if adjusted in accordance with the Contract Agreement (including conditions pursuant to permits received specific to the Project) will be met and adhered to. Such guarantee is subject to demonstration through Acceptance Testing, as set forth in Section 3 of Appendix A, prior to the Actual Acceptance Date being reached.

TABLE B-5

SANITARY LANDFILL DESIGN AND OPERATION GUIDELINES

Item Description	Regulation	Comments
1. Surface and Groundwater Contamination	Leachate control is required where water table is less than 5 feet below ground surface or within 500 feet of a water supply well.	The USEPA has designated the Biscayne Aquifer as a sole source water supply and no degradation is allowable.
	Surface runoff collection, control and treatment shall be provided for.	Permanent leachate control should be provided, i.e., impermeable soil layer or membrane liner with leachate recycle or treatment.
	Landfills shall not be located in areas of frequent and periodic flooding.	Berms, dikes or ditch should be provided at toe of landfill cells.
	Landfills shall not be within 200 feet of any water body except canals used to lower site water tables or on-site water bodies which do not discharge from the site.	A minimum of 200 feet must be maintained between the landfill and adjacent connected water bodies.
2. Hazardous Waste Disposal	Method of disposal must be approved; determined on a case by case basis.	Wastes which cannot be rendered non-hazardous and which present a harmful condition to human health or air or water quality should not be landfilled.
3. Infectious Waste	Prohibited - must be incinerated.	Prohibited
4. Burning	No open burning of solid waste is permitted.	Prohibited

TABLE B-5
(Continued)

SANITARY LANDFILL DESIGN AND OPERATION GUIDELINES

Item Description	Regulation	Comments
5. Monitor Wells	At least 3 monitoring wells shall be constructed and sampled in accordance with EPA/530/SW-611. One well shall be upgradient of the site, one well at the downstream boundary of the site and one at the downstream boundary of the first cell filled. Background water quality data shall be recorded.	Three wells is a minimum for a Class I landfill. Additional wells may be required by the DER dependent on actual design, operation and hydrogeologic conditions.
6. Initial Cover	Site shall receive an initial cover (6 inches of compacted soil) at the end of working day.	All solid waste on the site should be covered daily with 6 inches of compacted soil.
7. Solid Waste	Scales or volume estimates are required with quantitative records available to DER upon request.	Scales should be provided at high volume landfills (greater than 50 TPD).
8. Working Face	The working face shall be kept as narrow as is consistent with proper operation of equipment and to minimize exposed areas.	Provisions should be made signs to limit the areas where waste is discharged, spread and compacted to 100 feet or less.
9. Attendent	An attendent shall be on site during landfill hours of operation.	Supervisory personnel and a trained equipment operator should be in attendence during hours of operation.
10. Fire Protection	Adequate fire protection facilities shall be provided.	Earth stockpiles and adequate water supplies should be available on site.

TABLE B-5
(Continued)

SANITARY LANDFILL DESIGN AND OPERATION GUIDELINES

Item Description	Regulation	Comments
11. Access Road	An all weather access road shall be provided.	A minimum 24 foot wide, permanent paved road from the public thoroughfare to and around the work area should be provided.
12. Potable water supply, employee shelter, handwash and toilet facilities, electric service, equipment washout facilities	Encouraged but not required.	All recommended.
13. Communication Facilities	Required.	Telephone service should be provided.
14. Equipment and reserve equipment	Required.	Required.
15. Dust Control	Provisions for dust control shall be provided such as approved chemicals, oils, or water sprays.	Dust control material should be readily available.
16. Litter Control	Portable fences shall be provided.	Portable fences should be provided at the working face.
17. Scavenging	Must be controlled by local facility authority.	No unsupervised scavenging should be permitted.
18. Pesticides	Vector control shall be provided pursuant to Chapter 5E-2 FAC of the Florida Department of Agriculture and Consumer Services.	A schedule of insect and rodent control should be provided by a contracted exterminator.

TABLE B-5
(Continued)

SANITARY LANDFILL DESIGN AND OPERATION GUIDELINES

Item Description	Regulation	Comments
19. Aesthetics	Screening must be provided where practical for a landfill in view of a major public thoroughfare.	A vegetation buffer zone of 100 feet (or grass covered berm) should be provided on the site perimeter.
20. Special Waste Handling	Waste sludges shall be accepted only where alternate disposal methods are not available and when such disposal does not violate the regulations.	Municipal sludges should only be accepted on an emergency/ interim basis.
	Abandoned vehicles may only be stored temporarily.	Arrangements must be made for frequent removal to an automobile recycler.
	Milled solid waste without daily soil cover may be acceptable, contingent on conditions.	Requires milling facility and all leachate control and operation conditions listed above.
21. Landfill Liner	Permeability of Class I landfill liner must be 1 x 10^{-7} cm/sec or less.	A natural clay or synthetic liner with a permeability of 1 x 10^{-7} cm/sec must be provided.
22. Proximity to Airpots	Landfill should not be located within 10,000 feet of closest point of any runway at a State licensed airport used for turbojet aircraft or within 5,000 feet of a runway used for piston engine type aircraft unless FAA or DER approve.	Minimum required distances must be maintained.

V

Appendix 10.12

Summary Update of Research Projects with Incinerator Bottom Ash Residue

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COMMONWEALTH OF MASSACHUSETTS
Executive Office of Environmental Affairs
Department of Environmental Management
Bureau of Solid Waste Disposal
Boston, Massachusetts 02202

FEBRUARY 1982

Governor Michael S. Dukakis

Secretary of Environmental Affairs James S. Hoyte

Publication of this Document Approved by John Manton, State Purchasing Agent

NUMBER 3

SUMMARY UPDATE OF RESEARCH PROJECTS WITH RESCO INCINERATOR RESIDUE

1977-1981

The INTERIM REPORT, already in the possession of the Department of Environmental Quality Engineering carries the work through July 1979. Since then work with RESCO incinerator residue has taken the following several directions:

A. Continuing evaluation of potential ash/wetland interaction, including:

   1) heavy metal monitoring of ground water

   2) heavy metal monitoring of soils beneath and downstream of residue piles

   3) investigation of residue impact on wetland soil algal populations

   4) investigation (bi-yearly) of residue impact on higher plant populations

B. Leaching studies have been continued and expanded to include soil/residue mixtures in addition to preliminary residue leachate studies.

   1) event monitoring of rainfall

      a) amount

      b) pH

      c) chemical analysis (heavy metals)

   2) event monitoring of leachate from residue and residue/soil columns

      a) pH

      b) soluble salts

      c) chemical analysis (heavy metals)

RESULTS

Briefly, the results of these various studies to date are as follows (by number category)

A. 1) No additional contamination of ground water from residue heavy metals has been observed to date.

   2) No significant increase in heavy metal concentrations has been found in soil beneath the residue piles. A significant increase in soil Pb has been observed in the wetland soils immediately adjacent to the residue pile.

There has been no significant increase in the concentration of any other trace heavy metals measured. (Cd, Zn, Ni, Cu, Cr.)

3) No deleterious impact on the soil algae has been observed (See paper by Mika).

4) No deleterious impact on wetland higher plants has been observed as of summer '79. (See abstract)

B. 1) event monitoring of rainfall

   a) the amount of rainfall passing through the leaching columns of pure ash residue has been 360,000 ml to date. (Represents about 60 inches of rainfall).

   b) the mean pH value of rainfall to date is 4.0

   c) chemical analysis of the rainfall events to date indicate that only Pb is present in appreciable amounts in the wet precipitation falling on the Waltham collection station.

2) event monitoring of the leachate from residue and residue/soil columns

   a) pH of pure residue leachate to date continues to range between 7.6 - 8.2. Mean is 7.9.

   b) pH of residue/soil or soil/residue leachates range between 5.7 - 7.7 and 7.5 - 8.2 respectively. pH of soil leachate ranges between 5.8 - 7.1.

   c) soluble salts are all below 100.

   d) Mean heavy metal content in leachates are as follows:
   (all concentrations are in PPM)

	Pb	Ni	Cd	Cu	Cr	Zn
Residue	0.18	0.07	0.006	0.027	0.037	0.07
Soil	0.19	0.03	0.006	0.03	0.035	0.05
Residue/soil	0.32	0.04	0.006	0.025	0.035	0.075
Soil/residue	0.375	0.07	0.008	0.025	0.035	0.105
Rain	0.173	0.038	0.013	0.023	0.03	0.05

CONCLUSIONS

The data indicate that the incinerator bottom/fly ash mix (residue) is highly buffered; that the buffering capacity is massive and persistant; that heavy metals are chemically bound in the residue matrix, and that the residue can raise the pH of leaching acid rainwater from 4.0 - 7.8 without a concomitant release of heavy metals into the leachate. The data to date suggest that incinerator residue (bottom/fly ash) might be used as a landfill and may improve landfill management by buffering acid rain percolating through the landfill, thereby reducing the leaching of heavy metals from the residue as well as from other metal-containing materials which might be present in the landfill. Growth of a grass cover crop on the residue surface presents no problems in the greenhouse or in the field.

Respectfully submitted:

William A Feder

William A. Feder
Professor

Date 2/18/82

Jane S. Mika

Jane S. Mika

Suburban Experiment Station
University of Massachusetts
240 Beaver Street
Waltham, MA 02254

Special

NUMBER 4

The Commonwealth of Massachusetts

Department of Environmental Quality Engineering

Water Supply Analysis (mg. per liter)

Waltham

Collector: Grogan & McKay

Source A Bottom Ash Area - Location #8A
Source B #8B
Source C #8C
Source D #9A
Source E #9B
Source F #9C

	A	B	C	D	E	F
Sample No.	543480	481	482	483	484	485
Date of Collection	8/9/77					
Date of Receipt	3/31/77					
TURBIDITY	0.7	2.4	2.2	0.9	0.6	4.6
SEDIMENT	0	1	---	0	0	hea[illegible]
COLOR	0	20	100	0	10	20
ODOR	0	0	---	0	0	35
pH	7.8	7.9	7.9	7.8	7.2	7.1
ALKALINITY-Total($CaCO_3$)	31	31	38	32	36	36
HARDNESS($CaCO_3$)	70.	70.	39.	67.	74.	35.
CALCIUM(Ca)	20.	18.	10.	20.	19.	13.
MAGNESIUM(Mg)	4.8	6.0	3.3	4.0	6.5	2.5
SODIUM(Na)	7.2	7.5	7.0	8.0	7.0	8.0
POTASSIUM(K)	1.7	2.5	1.5	1.7	1.5	2.0
IRON(Fe)	.03	.45	1.5	.05	.05	.79
MANGANESE(Mn)	.18	.10	.01	.35	.05	.02
SILICA(SiO_2)	12.	13.	27.	14.	16.	26.
SULFATE(SO_4)	27	36	1	27	36	2
CHLORIDE(Cl)	21.	18.	19.	21.	19.	14.
SPEC.COND.(micromhos/cm)	184	184	---	172	185	116
NITROGEN(AMMONIA)	.01	.01	.11	.07	.02	.16
NITROGEN(NITRATE)	1.6	0.0	0.1	1.4	0.8	0.0
NITROGEN(NITRITE)	.002	.000	.021	.003	.003	.000
COPPER(Cu)	.00	.00	.00	.00	.00	.00

NUMBER 5

A SUMMARY OF RESEARCH CONDUCTED AT THE SUBURBAN EXPERIMENT STATION OF THE UNIVERSITY OF MASSACHUSETTS IN COOPERATION WITH THE BUREAU OF SOLID WASTE MANAGEMENT, THE DEPARTMENT OF ENVIRONMENTAL QUALITY ENGINEERING, THE DEPARTMENT OF PUBLIC WORKS, AND THE RESCO INCINERATION FACILITY, TO EVALUATE THE ENVIRONMENTAL IMPACT AND UTILIZATION OF INCINERATOR RESIDUE

Progress Report 1977-1981

Submitted to the Bureau of Solid Waste Management

Suburban Experiment Station
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December 31, 1981

RESEARCH OVERVIEW

The research conducted over the past several years through the cooperative efforts of the University of Massachusetts and the following state agencies: BSWM, DEQE, & DPW, has been unique in scope and nature. The characterization and potential utilization of incinerator residues is becoming increasingly necessary with the realization that: 1) land available for waste disposal is decreasing, 2) regulations implemented to govern waste disposal are stringent and complex, and 3) the need for alternative energy sources is imperative. Incineration of municipal refuse addresses points 1 and 3 above, however the by-products of this technology, including both fly ash and bottom ash, may impede progress due mainly to lack of information, and questionable regulation. The purpose of the studies being conducted at the Suburban Experiment Station is to supply the information needed to properly regulate incineration by-products so that refuse incineration may not be wrongly sequestered.

The several studies described in this report were designed to assess the direct and indirect interaction of incinerator residues with the natural environment. Direct effects include acute effects on indigenous and introduced plant species, metal uptake, and groundwater pollution. Indirect effects may include chronic effects on plant growth and reproduction, disturbance of plant community stability, and soil erosion. Quantifying impacts in the natural environment necessitates collection of data over time. The length of time necessary to measure these impacts is presently unknown. The data collected from the long-term projects at Waltham and North Andover will be invaluable for providing components with which models may be designed to predict heavy metal movement through ecosystem compartments. Since the initial expenditures have been made, these projects should continue to be supported by the state, at a reasonable cost, for at least 5 more years, so that the time and effort to date will not have been wasted.

Incineration of solid waste is gaining popularity and support. Massachusetts is currently closing many existing landfill disposal sites and disposal alternatives must be properly assessed and implemented. Incineration of municipal refuse not only drastically reduces refuse volume, but can also provide resources for land reclamation (reducing our reliance on valuable top soil), road construction (creating a possible market for aggregate substitute) and energy alternatives. Other states are now looking to Massachusetts for support and information with which they may justify or expand refuse incineration. Any support must be based on sound information regarding both the practicality and safety of residue utilization. Massachusetts is currently the forerunner in this type of research. This unique position should not be lost.

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INTRODUCTION AND PURPOSE

The recovery of useful energy from solid wastes can be achieved through incineration of these wastes using a variety of technologies developed in Europe. The vanRoll and the Martin Moving Grate systems are two that are being adapted for use in the U.S. Another type of technology, not considered in this report, produces a solid or liquid fuel from the waste and this fuel is then distributed to the final consumer.

The system considered in this report, converts solid wastes to heat which in turn converts water to steam. The steam is piped to a nearby consumer, and the waste steam and excess heat is recycled to maintain the system temperature. Waste gases and particulates are scrubbed from the stacks and, in the system under discussion, these fly ash components are combined with the heavier bottom ash residues to produce an ash residue which constitutes the unburnable portion of the waste feed stock. The mixed ash residue is cooled by quenching in lime water and then graded to recover ferrous metals and other materials of possible commercial value. The final product is a heterogeneous mixture of carbonaceous and silicaceous matter, metal oxides, plus a certain percentage of fine particulates which represent the fly ash component of the burning process.

In Massachusetts, incinerator residue is currently regulated as a solid waste. These regulations prohibit marketing and place restrictions on disposal of the residue. This limits the economic potential of a waste disposal technology that may 1) limit biological contamination from municipal landfills by a reduction in percent organic matter; 2) reduce the amount of land needed for waste disposal, and 3) increase regional energy supplies by utilizing waste steam for cogeneration. Variances to reclassify the residue will not be issued by state regulatory agencies until it has been determined that the residue is nonpolluting.

The paucity of suitable landfill sites coupled with the economic benefits accruing from possible commercial uses of the ash have prompted these studies which attempt to describe and quantify the effects of this metalliferous residue on the integrity of the environment. The metals of concern are among those elements considered as potential toxins in water supplies, and either primary or secondary standards have been established for all but nickel. Though heavy metals are also present in untreated refuse, it is the relatively greater concentration of metals in residue landfilling that increases the pollutant potential of the residue.

If it can be shown that land application of the residue exerts a minimal impact on the environment, and that residue metals will not contaminate the groundwater, then it would be possible to reclassify the residues to allow for commercial marketing, and enhance the resource recovery process by transforming nearly 100% of the initial raw waste into useful products or available energy. The background, methods and results of the several integrated research projects undertaken to demonstrate and quantify the environmental impact and market potential of RESCO incinerator ash residue are described in the body of this report.

EXECUTIVE SUMMARY

The following summary outlines the scope of research undertaken at the Suburban Experiment Station, University of Massachusetts, on municipal incinerator residue from the RESCO incinerator, Saugus, Mass. The outline and following report describe several field and laboratory studies conducted during the period 1977 to 1981.

A. Evaluation of potential residue/wetland interaction, including:

   1) heavy metal monitoring of groundwater

   2) heavy metal monitoring of soils

   3) investigation of residue impact on higher plant populations

   4) investigation of residue impact on soil algal populations

B. Leaching studies involving acid rain deposition on residue and soil-residue mixtures

   1) event monitoring of rainfall, including:

      a) amount
      b) pH
      c) chemical analysis (heavy metals)

   2) event monitoring of leachate from residue and soil/residue columns, including:

      a) pH
      b) soluble salts
      c) chemical analysis (heavy metals)

C. Evaluation of residue as a horticultural medium

   1) greenhouse studies on raised benches, including:

      a) grasses
      b) flowering plants and vegetables
      c) "roadside" simulation

   2) turf plots

   3) pot studies to identify horticultural potential by examining:

      a) growth, vigor and flower production
      b) metal uptake

RESULTS

Briefly, the results of these various studies to date are as follows: (by letter, number category)

A. 1) No additional heavy metal contamination of groundwater from residue landfill has been observed to date.

2) Of the six heavy metals monitored (Pb, Cd, Zn, Ni, Cr and Cu), only lead (Pb) was found to have increased significantly in soil adjacent to the residue landfill one year following residue deposition.

3) No deleterious impact has been observed on the wetland higher plant community.

4) No deleterious impact was observed in the soil algal community.

B. 1) event monitoring of rainfall

a) The amount of rainfall passing through leaching columns of pure residue has been 360,000 ml to date (represents about 60 inches of rainfall).

b) The mean pH of rainfall to date is 4.0.

c) Chemical analysis of the rainfall events to date indicate that Pb may be the only metal present in appreciable amounts in the wet precipitation falling on the Waltham collecting station.

2) event monitoring of leachates

a) The pH of pure residue leachate to date continues to range between 7.6 and 8.2. Mean pH is 7.9.

b) The pH of residue/soil or soil/residue leachates range between 5.7 to 7.7 and 7.5 to 8.2 respectively. Soil leachate pH ranges between 5.8 and 7.1.

c) Leachate soluble salts are all below 100.

d) Mean heavy metal content in leachates are as follows:

	Pb	Ni	Cd	Cu	Cr	Zn
Residue	0.18[1/]	0.07	0.006	0.027	0.037	0.07
Soil	0.19	0.03	0.006	0.03	0.035	0.05
Residue/soil	0.32	0.04	0.006	0.025	0.035	0.075
Soil/residue	0.375	0.07	0.008	0.025	0.035	0.105
Rain	0.173	0.038	0.013	0.023	0.03	0.05

[1/] all concentrations in p.p.m. (parts per million)

C. 1) Greenhouse studies

a) Flooding the raised beds with tap water reduced the pH to 7.2 and soluble salts to below 100. Both annual and perennial rye grasses grew well directly on the bare residue.

b) Residue supported the growth of lettuce, corn, tobacco, geraniums, marigolds, zinnias, petunias, chrysanthemums, narcissus, and daffodils. All plants grew normally on the residue, produced normal flowers, fruit and seed where applicable.

c) Grass grew equally well on the residue hillside, and the soil below. Analysis showed that minimal heavy metal leaching occurred vertically through the residue, but heavy metals were not detected in the runoff.

2) RESCO residue proved suitable as a subsoil layer for turf construction.

3) Pot studies

a) All plant species grown produced a commercially acceptable crop utilizing an incinerator residue medium.

b) Heavy metal uptake indicated that an insignificant portion of the heavy metal load in RESCO residue is "available".

CONCLUSIONS

A. Wetland/Incinerator Residue Interactions

Following 15 months of wetland/incinerator residue interaction, the accumulated chemical and biological data indicate that heavy metals have not leached (with the possible exception of lead), and/or are not available in quantities sufficient to disturb the structure of the wetland plant communities. The pollutant/ecosystem interaction represents one in which the soils (or biota) are acting as unaffected sinks (Class I), due to the possible accumulation of lead. There is not sufficient evidence at this time to predict future impacts. The indication of lead mobility, however, warrants the continued monitoring of all ecosystem compartments.

B. Leaching Studies

Extensive leaching studies with natural rain have revealed no significant losses of heavy metals from the residue in spite of a mean rainfall pH of 4.0. The residue has a high buffering capacity which has persisted undiminshed for over 3 years, during which time about 360,000 ml (60 inches) of rain has passed through the residue.

C. Horticultural Studies

RESCO residue is an excellent medium for growth of turf and horticulturally valuable plant materials such as bedding and pot plants like chrysanthemums, poinsettias, geraniums, bulb plants etc. Mixtures containing RESCO residue, peat, and soil perform as well as commercial soil mixes and several soilless potting media.

RESCO residue will also perform well as a subsoil for building golf courses and as fill for grading highway slopes and median strips. After two years' contact with soil and cropping with a variety of plants, the RESCO residue takes on the character of a loose, granular soil-like material which drains well, is easy to work, and is quite resistant to erosion from wind or water.

RECOMMENDATIONS

The data indicate that incinerator bottom/fly ash mix (residue) is highly buffered; that the buffering capacity is massive and persistant; that heavy metals are chemically bound in the residue matrix, and that the residue can raise the pH of leaching acid rainwater from 4.0 - 7.8 without a concomitant release of heavy metals into the leachate. The data to date suggest that incinerator residue (bottom/fly ash) might be used as a landfill and may improve landfill management by buffering acid rain percolating through the landfill, thereby reducing the leaching of heavy metals from the residue as well as from other metal-containing materials which might be present in the landfill. Growth of a grass cover crop on the residue surface presents no problems in the greenhouse or in the field.

WETLAND STUDIES

Introduction

The mobility and availability of residue heavy metals in the terrestrial environment are the problems addressed in the following research. Mobility is the movement of materials both from the source and through ecosystem compartments. Availability is the efficiency with which the materials enter biological systems. Both parameters should be integral components in the classification of potentially hazardous wastes. Current federal regulations designed to test for leachate toxicity are limited in their scope to criteria established for drinking water supplies. Criteria for terrestrial ecosystems have yet to be addressed by regulatory agencies. Incinerator residues and sewage sludges (both potential sources of toxic metals) are often land applied. Heavy metals, if released through leaching, may be effectively filtered out by soils, which are the primary sink for metallic cations. Because soils are also the primary sink for excess acidity, (exacerbated through acid precipitation), heavy metals, being more mobile in acid environments, may be initially bound by soil organics and later released due to increasing soil acidity.

In order to assess the impact of residue landfilling, a long term field study was initiated in the spring of 1978 with the disposal of incinerator residue adjacent to a freshwater wetland. In addition to monitoring heavy metal mobility in soil and groundwater, metal availability and toxicity were assessed through repeated sampling of the plant communities over time and distance from residue deposition.

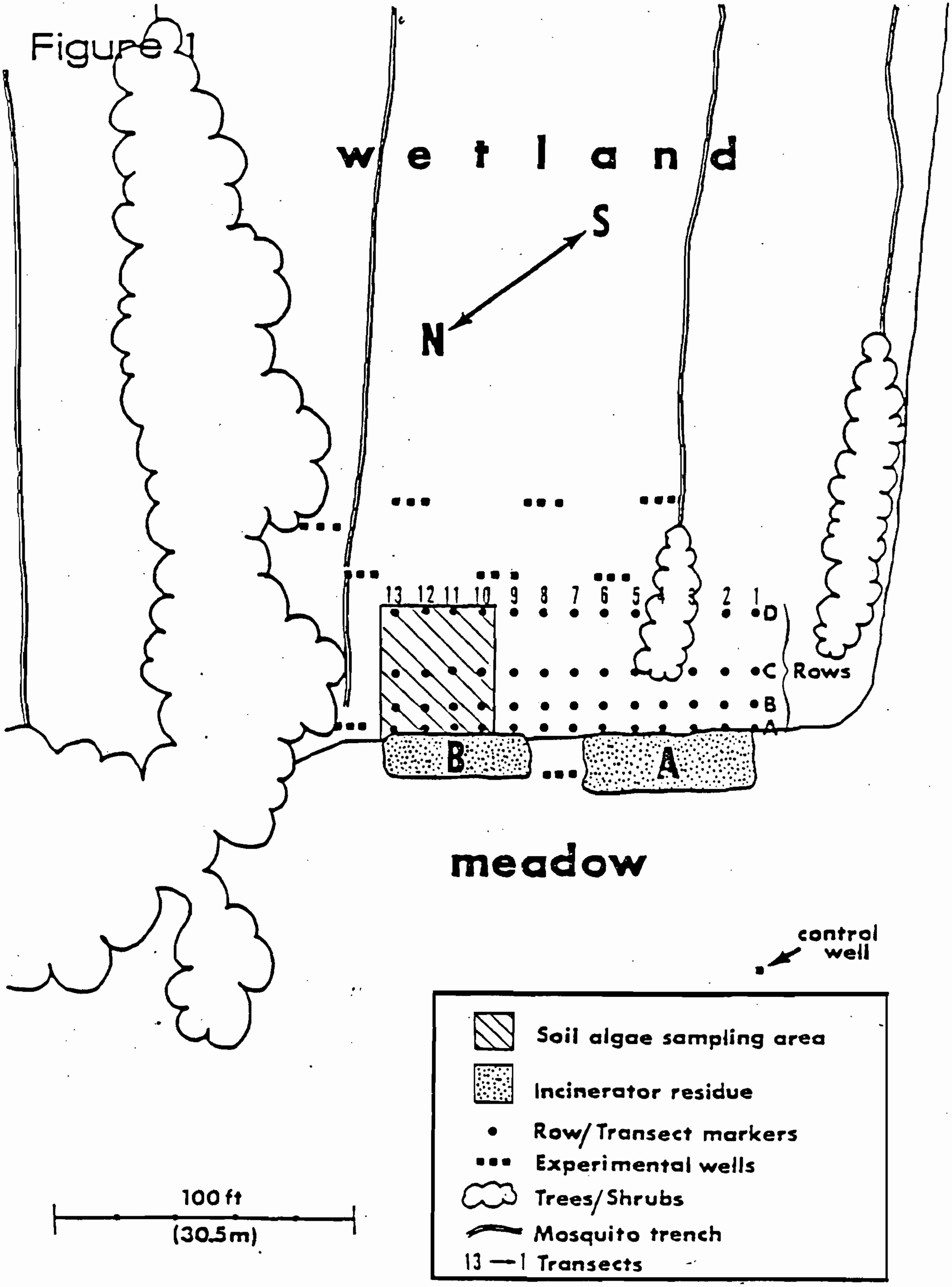
Description of Study Site

The experimental site encompasses approximately 484m^2 (5200 ft^2) along the border of a wetland located on the property of the University of Massachusetts Agricultural Experiment Station, Waltham, Mass. (Figure 1.) The site is transversed by 13 line transects, at 3.05 (10 Ft) intervals, which extend approximately 12.2 m (40 ft) into the wetland. These permanent transects were established in 1977 and continue to serve as sampling locations for soils, herbaceous plants, and algal communities. The predominant wetland soil types are peat and muck, intermixed and underlain with sand and gravel. A layer of till or bedrock is encountered approximately 7.6m (25 ft) below the surface. Flooding normally occurs only in the spring and winter, though standing water may persist through the summer months in semipermanent pools and mosquito trenches. Twenty seven wells are located at various depths and distances into the wetland for groundwater monitoring. A "control" well is located upland from the wetland.

In June, 1978, two 30m^3 volumes of incinerator residue were deposited in the meadow, along the northeast border of the wetland, adjacent to the experimental site. At one location the residue was laid over the existing groundcover. At the second location, the residue was deposited to a depth of 0.6 m (2 ft) and brought up to grade

Figure 1. Map of wetland and experimental site. Row/transect markers designate soil and vegetation sampling locations. Incinerator residue at site "A" was deposited over existing groundcover; residue at site "B" was deposited to a depth of 0.6m (2 ft), and brought up to grade. Higher plants were sampled along the 13 transects at rows A, B, C & D. Soil and soil algae were sampled within the hatched area (transects 10-13). Groundwater was sampled at 3 depth in each of the well locations.

Figure 1


w e t l a n d
S
N
13 12 11 10 9 8 7 6 5 4 3 2 1
D
C
B
A
Rows
B
A
meadow
control well
Soil algae sampling area
Incinerator residue
Row/Transect markers
Experimental wells
Trees/Shrubs
Mosquito trench
13 — 1 Transects
100 ft
(30.5m)

Groundwater

Groundwater samples were collected and analyzed by cooperating state agencies. The well locations are included in Figure 1. Samples were analyzed for various chemical constituents including Pb, Cd, Cr, Ni, Zn, and Cu. Samples from the 27 experimental wells were not significantly different in metal concentrations and, therefore, data were averaged for the present analyses. Over a two year period, ten groundwater collections were made: two prior to the residue deposition (10/77 and 4/78); three following residue deposition in 1978 (5/78, 7/78, and 12/78); and five in 1979 (5/79, 6/79, 7/79, and 9/79, and 11/79). For analysis, these collections were grouped into three collection periods: "Pre-ash"; "1978 Post-ash"; and 1979". The grouping facilitated statistical analysis and should have reduced the standard error of analysis over time.

Kruskal-Wallis one-way ANOVA was used to test for differences in metal concentrations over space (wells # 2 through # 10) and over time (pre-and-post ash collection periods). Metal concentrations from the experimental wells (#2-#10) were also compared to those from the control well (# 1) to factor in normal fluctuations in groundwater.

The results of k-sample testing (Kruskal-Wallis one-way ANOVA) of metal concentrations in groundwater over space (wells # 2 through # 10) and over time ("pre-ash", "1978 post-ash", and "1979") are presented in Table 1. With the exception of cadmium, the probability of such levels occurring over space exceeded 70 percent, and, therefore, the variations were not significant. (The range of probability for cadmium was between 20 and 30 percent, also insignificant.) Thus, the spacial distribution of wells, relative to the residue landfill, was not a factor in heavy metal distribution in groundwater during the two year collection period (10/1977 through 11/1979).

The concentrations of Pb, Cd, Cr, and Ni from the experimental wells did, however, differ significantly over time. The heavy metal concentrations in the "control site" (well # 1, located upland from the residue) were equal to, and often exceeded those from the experimental wells (Figures 2 and 3). These significant changes in the levels of Pb, Cd, Cr, and Ni may have been the result of normal yearly fluctuations, or the standard error of analysis.

Primary drinking water standards were either equalled or exceeded for lead, chromium and cadmium in both experimental and control wells (Figure 2). The current secondary standards for zinc and copper are 5 ppm and 1 ppm respectively; there is currently no standard for nickel.

The heavy metal concentrations in groundwater varied significantly only over time (as did soil metals) and, therefore, these variations may have been partially a result of the standard error of analysis. Significant differences, in groundwater drawn from "experimental" wells, were found for lead, cadmium, chomium and nickel. These metal concentrations, however, were paralleled and often exceeded by the metal concentrations from the "control" well. These data indicate that significant differences in groundwater metals were not the result of residue leaching. Because lead and cadmium concentrations in the groundwater exceeded primary drinking water standards prior to residue disposal, care should be taken to avoid additional stress on the underlying aquifer.

Table 1. Kruskal-Wallis one-way ANOVA of metal concentrations in groundwater over distance (wells # 2 through # 10) and over time ("Pre-ash", "1978 Post-ash", and "1979"). Chi-square (X^2) values and associated probabilities are presented. Significant differences are indicated by one or more asterisks over the X^2 value.

DISTANCE ANALYSES (WELLS # 2 through # 10

	Pb	Cd	Cr	Cu	Ni	Zn
X^2	3.76	10.04	4.02	4.97	5.18	1.37
Prob.	$.8<p<.9$	$.2<p<.3$	$.8<p<.9$	$.7<p<.8$	$.7<p<.8$	$p>.99$
df=8						

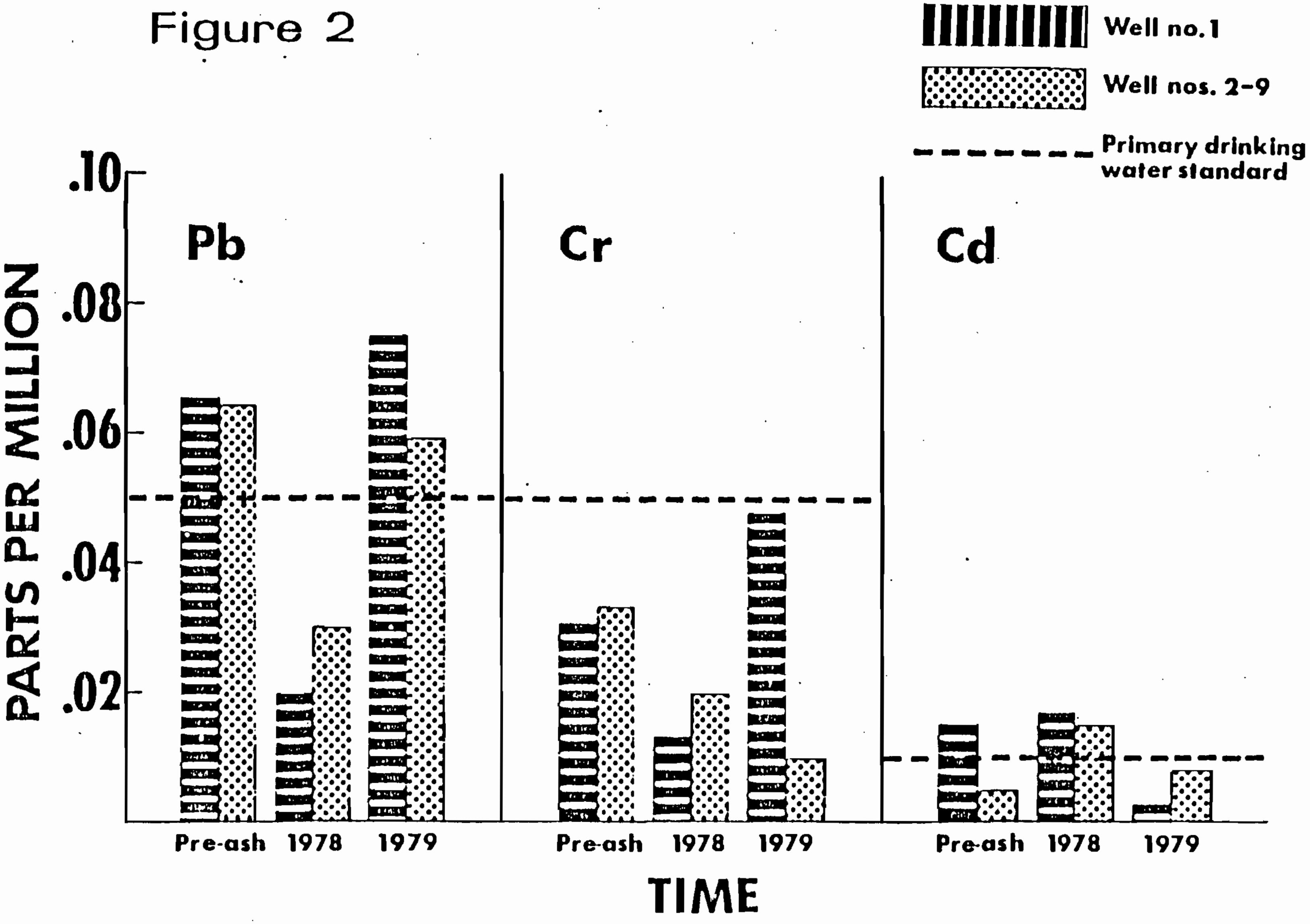
TIME ANALYSES (PRE-ASH, 1978 POST-ASH, and 1979)

	Pb	Cd	Cr	Cu	Ni	Zn
X^2	11.12***	8.41**	16.13***	0.77	10.65***	5.24
Prob.	$.001<p<.01$	$.01<p<.02$	$p<.001$	$.95<p<.98$	$.001<p<.01$	$.05<p<.10$
df=2						

** = significant difference at .02
*** = significant difference at .01

Figure 2. Lead (Pb), chromium (Cr), and cadmium (Cd) concentrations in groundwater over time. Metal concentrations for the "control well" (#1) are averaged over the 3 collection periods. Metal concentrations for the "experimental wells" (#2 through # 10) are averaged over space and time. (See text for explanation of grouping procedures.) Dashed lines indicate present drinking water standards.

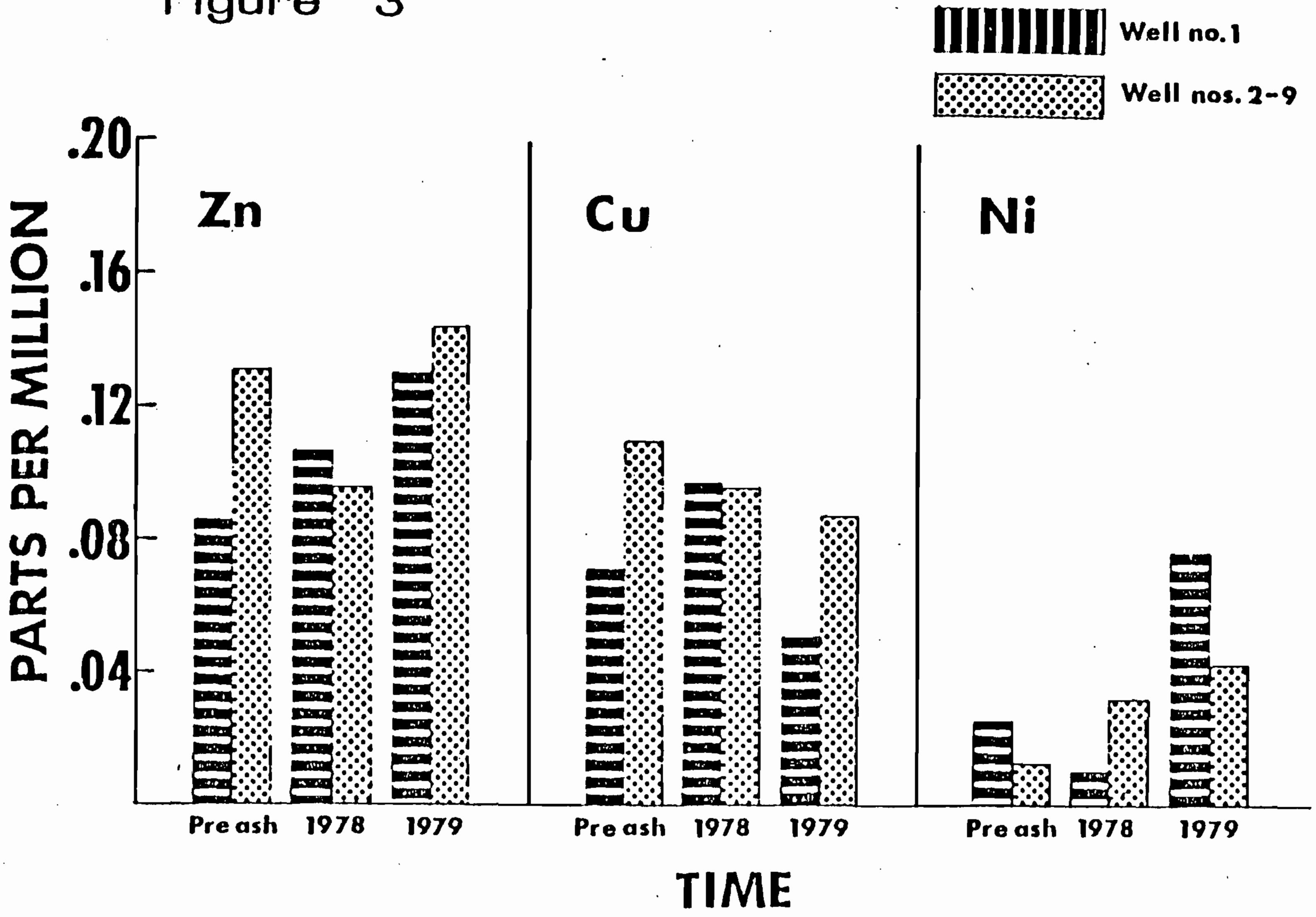
Figure 2



Well no. 1
Well nos. 2-9
Primary drinking water standard
Pb
Cr
Cd
PARTS PER MILLION
.10
.08
.06
.04
.02
Pre-ash
1978
1979
Pre-ash
1978
1979
Pre-ash
1978
1979
TIME

Figure 3. Zinc (Zn), copper (Cu), and nickel (Ni) concentrations in groundwater over time. Metal concentrations for the "control well" (#1) are averaged over time. Metal concentrations for the "experimental wells" (#2 through #10) are averaged over space and time.

Figure 3


Well no.1
Well nos. 2-9
.20
.16
.12
.08
.04
PARTS PER MILLION
Zn
Cu
Ni
Pre ash
1978
1979
Pre ash
1978
1979
Pre ash
1978
1979
TIME

Soil

Wetland soils were sampled one month (Series I, July 1978), three months (Series II, Sept. 1978), thirteen months (Series III, July 1979), and fifteen months (Series IV, Sept. 1979) following residue deposition. In addition to chemical analyses, the soils were used for the biological studies described in the following section. The procedures outlined below apply to all series.

The soil samples were taken at distances of 0m (Row A), 2.4m (Row B), 6.1m (Row c), and 12.2m (Row D) from the submerged residue (pile B) along transects numbered 10 through 13 (see Figure 1). Soil was collected to a depth of 13-18cm (after removal of the top 2-3 centimeters) at each of the 16 locations. The samples were dried at approximately 90°F for three weeks. The dry soils were thoroughly mixed and graded to uniform particle size.

Ten g of soil (1mm in diameter) from each sampling location (10A through 13D) in each experimental series (Series I through Series IV) were analyzed at the Massachusetts Department of Public Works Laboratory in Wellesley Hills, MA for the following heavy metals: lead (Pb), cadmium (Cd), chromium (Cr), copper (Cu), nickel (Ni) and zinc (Zn). Samples were analyzed using a Perkin Elmer atomic absorption spectrophotometer, model # 403. Significant differences in heavy metal concentration were tested using the Kruskal-Wallis one-way ANOVA over distance and time.

The results of soil heavy metal analyses are presented in Figures 4 through 7, fo Pb, Cd, Cr, Cu, Ni and Zn respectively. Each figure presents the mean concentration (ppm) of the metal as it varied through distance and time from residue deposition. There were no significant inter-row differences in soil metals through time. All test results are summarized in Table 2.

1) Lead (Figure 4). Lead was the only metal for which there was a significant increase through time in Rows A and B only (zero to 2.4m from residue landfill). This increase, nearest the wetland/residue border, resulted in similar lead levels in all rows by Series IV.

2) Cadmium (Figure 5). Cadmium concentration throughout the wetland changed significantly through time. The statistical significance of these changes increased with distance from .05 to .01. Significant differences over time were due in part to the relatively low soil Cd concentrations detected in Series III. If these unusually low concentrations (relative to Series I, II and IV) were the result of analytical error, and consequently removed from analysis, the Cd concentrations in Row A would no longer vary significantly, and the significance of inter-series differences in Rows B, C and D would be reduced to .05, .02, and .02 respectively. The soils in all rows, with the exception of Row A, decreased in Cd concentration over time. Therefore, as with lead, the change in cadmium concentration appeared to be a function of distance from the residue (or distance into the wetland).

3) Chromium (Figure 6). Chromium concentration changed significantly over time only in Rows B and D (2.4m and 12.2m from residue deposition). The direction of change was paralleled in all rows, and levels tended to decrease over time. Due to the extreme similarity in soil concentrations over time, it is probable that the significant differences between 1978 and 1979 were partially the result of a precision error in the analyses.

4) Copper, nickel and zinc (Figure 7). There were no significant changes in the soil concentrations of these metals over time.

Table 2. Kruskal-Wallis one-way ANOVA of soil metal concentrations over distance and time. Significant differences are indicated by one or more asterisks over the chi-square (X^2) value.

DISTANCE ANALYSES (ROWS A through D)

Series	Pb	Cd	Cr	Cu	Ni	Zn
I	4.17	3.76	1.25	3.36	1.45	4.45
II	3.06	1.64	1.84	1.80	1.31	2.47
III	3.40	4.87	1.40	7.74	5.07	0.64
IV	2.46	7.45	1.44	6.39	0.53	2.43

TIME ANALYSES (SERIES I through IV)

Row	Pb	Cd	Cr	Cu	Ni	Zn
A	12.41***	9.42*	7.65	2.37	3.95	7.10
B	12.51***	11.18**	9.99**	3.49	6.01	6.72
C	2.83	13.35***	7.57	3.57	4.33	3.46
D	1.73	13.62***	12.36***	6.06	4.09	0.59

* = significant difference at .05; df=3
** = significant difference at .02; df=3
*** = significant difference at .01; df=3

Figure 4. Lead (Pb) concentrations in soil presented as a function of time (Series I-IV) in each Row (A, B, C and D). Lead concentrations represent the mean of 4 locations/row.

Figure 4

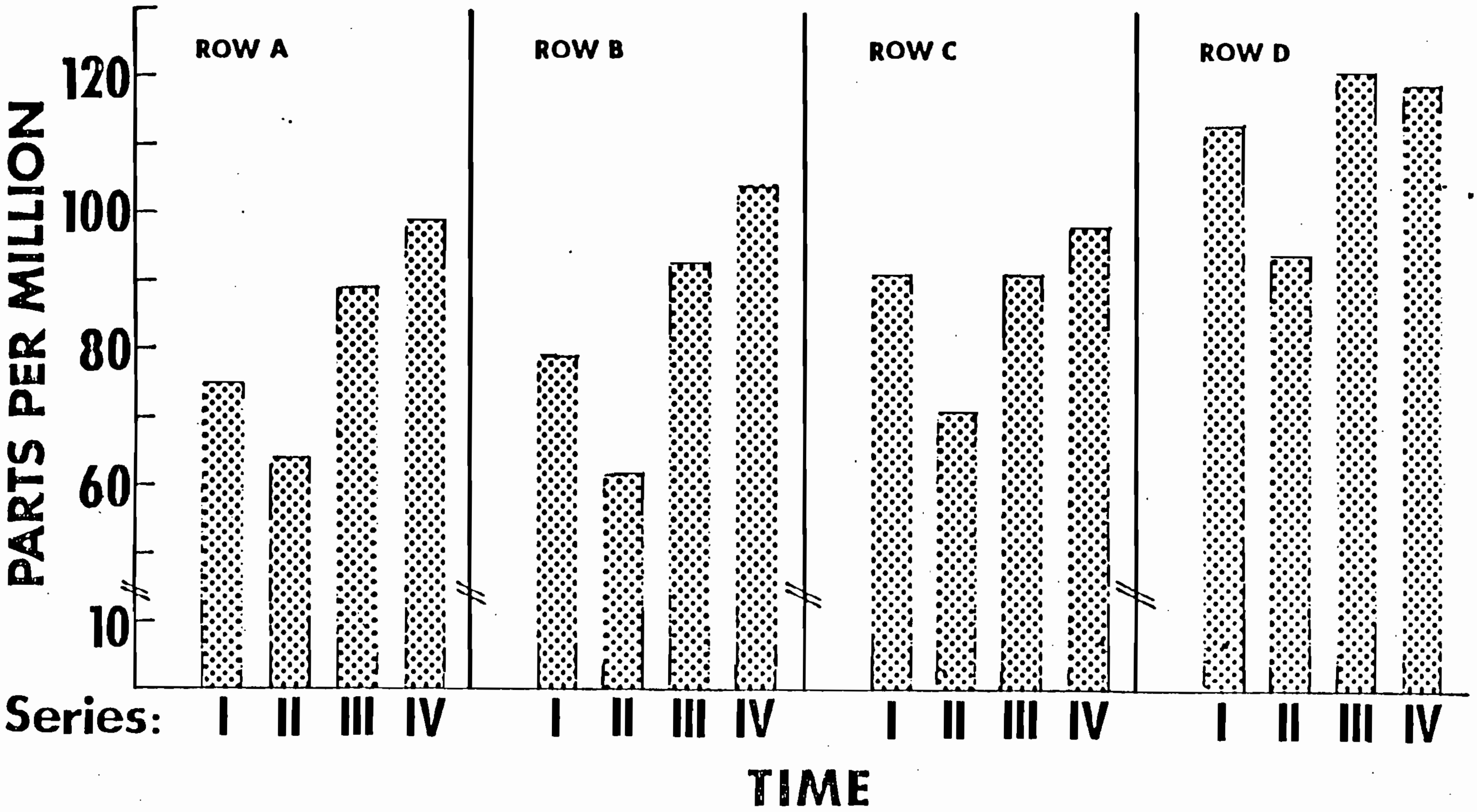

PARTS PER MILLION
120
100
80
60
10
ROW A
ROW B
ROW C
ROW D
Series:
I
II
III
IV
TIME

Figure 5. Cadmium (Cd) concentrations in soil presented as a function of time (Series I-IV) in each Row (A, B, C and D). Cd concentrations represent the mean of 4 locations/row.

Figure 5

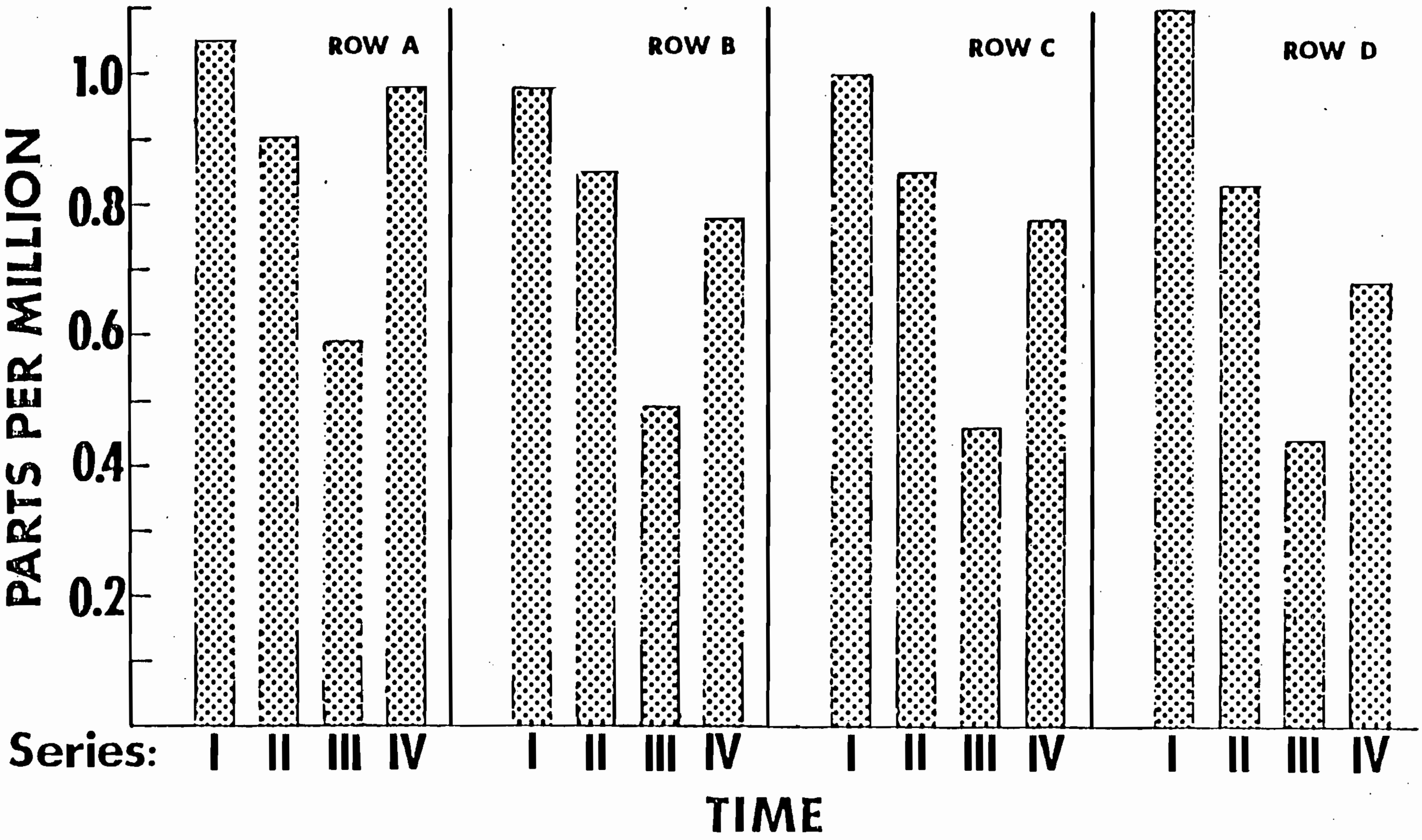

PARTS PER MILLION
1.0
0.8
0.6
0.4
0.2
ROW A
ROW B
ROW C
ROW D
Series:
I
II
III
IV
I
II
III
IV
I
II
III
IV
I
II
III
IV
TIME

Figure 6. Chromium (Cr) concentration in soil presented as a function of time (Series I-IV) in each Row (A, B, C and D). Metal concentrations represent the mean of 4 locations/row.

Figure 6

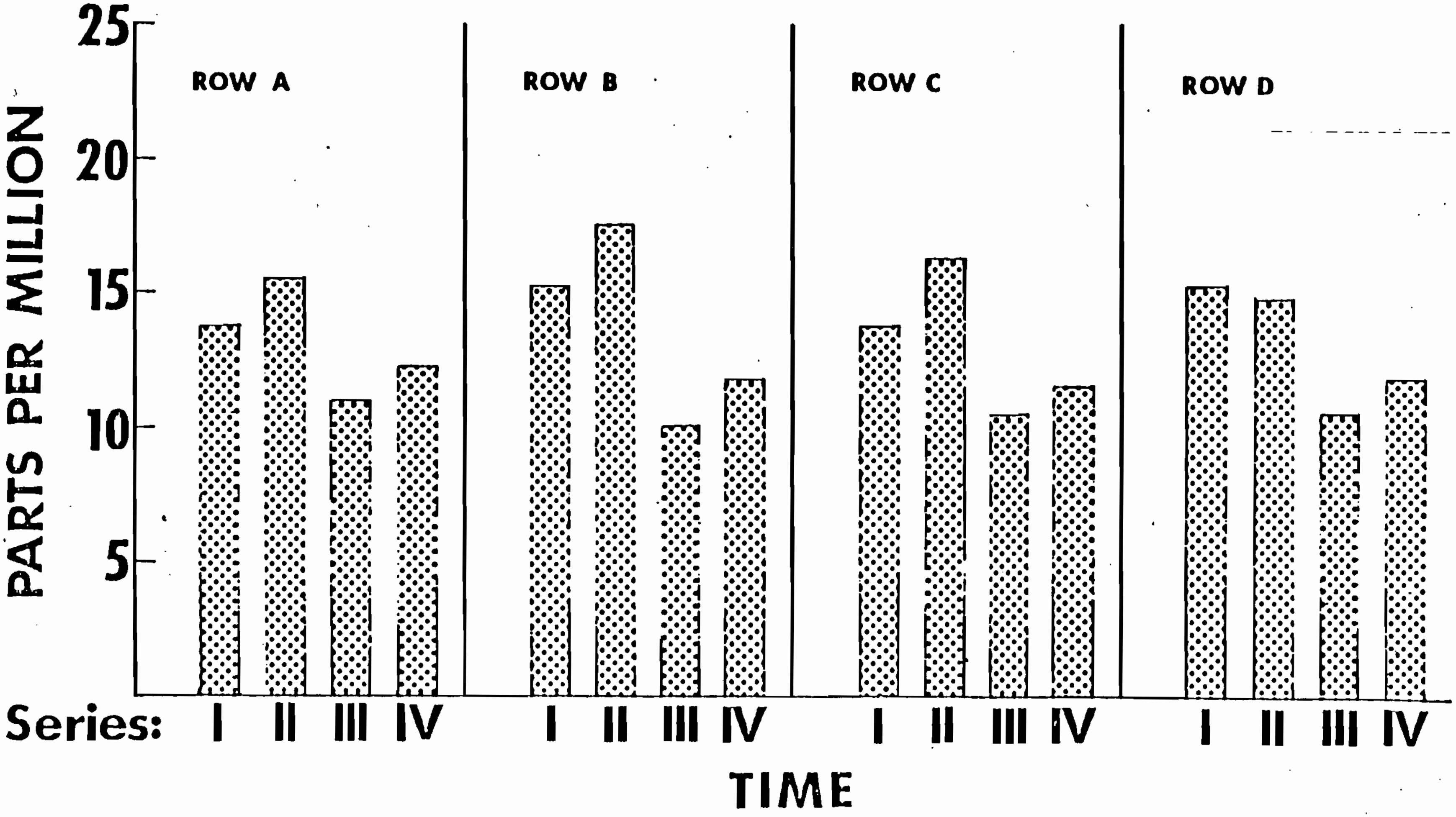
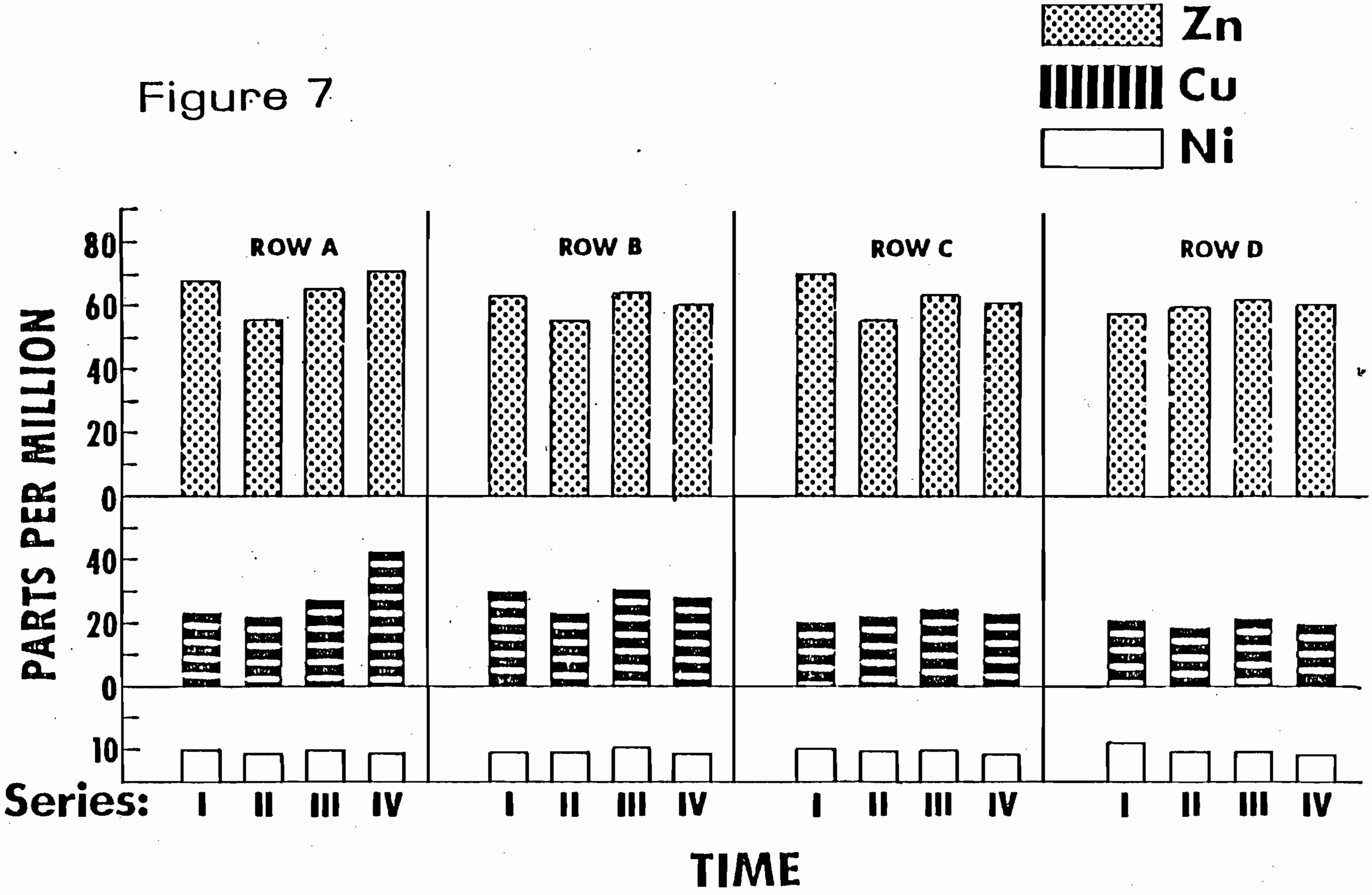

25
20
15
10
5
PARTS PER MILLION
ROW A
ROW B
ROW C
ROW D
Series:
I
II
III
IV
I
II
III
IV
I
II
III
IV
I
II
III
IV
TIME

Figure 7. Zinc (Zn), copper (Cu), and nickel (Ni) concentrations in soil presented as a function of time (Series I-IV) in each Row (A, B, C and D). Metal concentrations represent the mean of 4 locations/row.

Figure 7



Zn
Cu
Ni
ROW A
ROW B
ROW C
ROW D
80
60
40
20
0
40
20
0
10
PARTS PER MILLION
Series: I II III IV I II III IV I II III IV I II III IV
TIME

In summary, significant differences in soil metal concentrations were detected only when the samples were compared over time. Due to varying analytical precision (Olds [analytical chemist], pers. comm.), the significant differences observed in metal concentrations over time must be weighted with inter-row variance to detect those differences which may have been the result of a precision error. The temporal changes in lead and cadmium concentrations varied over distance; these changes may have been the result of residue/soil interactions.

Heavy metal concentration in the wetland soil, measured over time and distance from residue deposition indicated: 1) the availability of the metal in the ash residue; and 2) the relative mobility of the metal through the soil matrix. The soil samples from the wetland did not differ significantly in heavy metal concentrations over distance from the residue, but did differ significantly in lead, cadmium, and chromium over time. The fluctuations in metal concentration followed identical trends in all rows, and may have been partially the result of varying analytical precision. Of these three metals listed above, only lead increased significantly ($p < .01$) in soil near the residue landfill, and remained unchanged ($p > .70$) in soil farthest from the residue. Lead, therefore, may have leached from the residue landfill and accumulated in the organic soils near the wetland/residue interface. These results are not contradictory to expectations, in that, of the six metals tested, lead has been shown to be relatively more reactive to changes in pH and the presence of organic substrates. In conclusion, lead may have limited mobility in the residue, given an acid environment; however, mobility and availability may be restricted in organic soils.

Wetland Higher Plants

During the summer of 1977, the higher plants occupying the area proximal to the site of residue deposition were identified and quantified. The experimental area was sampled using quadrat analysis. A 4' X 4' frame was placed at rows A,B,C and D along each transect to obtain frequency and percent cover of the herbaceous species (see Figure 1). A total of 52 sites were sampled. Seventeen herbaceous species and several grasses were mapped (Table 3).

The residue was deposited at the wetland edge in June, 1978. The wetland plants bordering the residue showed no adverse effects, and soil pH remained slightly acid (5.0 to 5.5). Initial invasion of plants on to the ash piles was noted during the first growing season. Colonizing species appeared to come from the meadow, rather than from the wetland.

The higher plants were quantified again in the summer of 1979. The results indicated that the residue had not had any acute toxic impact on the wetland plant community. In general, the various species significantly increased in percent cover and density (Figure 8), without a concomitant change in diversity (Table 4).

Invasion of plants on to the residue piles was monitored throughout the growing season. Plant growth and community structure differed between the two residue piles. Pile "A" (residue deposited directly over existing groundcover) supported a generally more diverse plant community with greater biomass. Plant growth on pile "B" (residue deposited to a depth of 2 feet) was low and scrubby; the community was considerably less diverse.

In order to determine if heavy metal availability differed in the two residue piles leaves were collected from three plant species common to both, and analyzed for metal content (Table 5). Only the zinc concentration was consistently higher in plant tissue collected from pile "B". Preliminary investigation of the residue plant communities during spring, 1981, indicate that initial differences in growth andstructure still persist. Additional tissue samples will be collected in the next few months (summer, 1981) to determine what, if any, role metal availability has in determining the diversity and biomass of invading plant communities.

Table 3. Wetland higher plant species.

Common Name	Family	Scientific Name
Common Milkweed	Asclepiadaceae	*Asclepias Syriaca*
Creeping Thistle	Compositae	*Cirsium arvense*
Rock Goldenrod	Compositae	*Solidago canadensis*
Purple Loosestrife	Lythraceae	*Lythrum Salicaria*
Joe-Pye Weed	Compositae	*Eupatorium purpureum*
Cow Vetch	Fabaceae	*Vicia Cracca*
Jewel-Weed	Balsaminaceae	*Impatiens biflora*
Arrow-leaved Tear-thumb	Polygonaceae	*Tracaulon sagittatum*
Elderberry	Caprifoliaceae	*Sambucus canadensis*
Dodder	Cuscutaceae	*Cuscuta* sp.
Sensitive Fern	Polypodiaceae	*Onoclea sensibilis*
Marsh Shield-Fern	Polypodiaceae	*Dryopteris Thelypteris*
Corn Grass	Gramineae	*Panicum clandestinum*
Timothy	Gramineae	*Phleum pratense*
Meadow Foxtail	Gramineae	*Alopecurus pratensis*
Carex	Cyperaceae	*Carex* sp.
Fox Sedge	Cyperaceae	*Carex vulpinoidea*
Steeple-bush	Rosaceae	*Spiraea tomentosa*
Cinquefoil	Rosaceae	*Potentilla* sp.
Wood-sorrel	Oxalidaceae	*Xanthoxalis Brittoniae*
Aster	Compositae	*Aster dumosus*
Goldenrod	Compositae	*Solidago rugosa*

Figure 8. Pre- and post incinerator residue percent cover for wetland higher plants. Transects represent area occupied by individual species at designated distances from the residue landfill, before and following residue deposition.

Figure 8

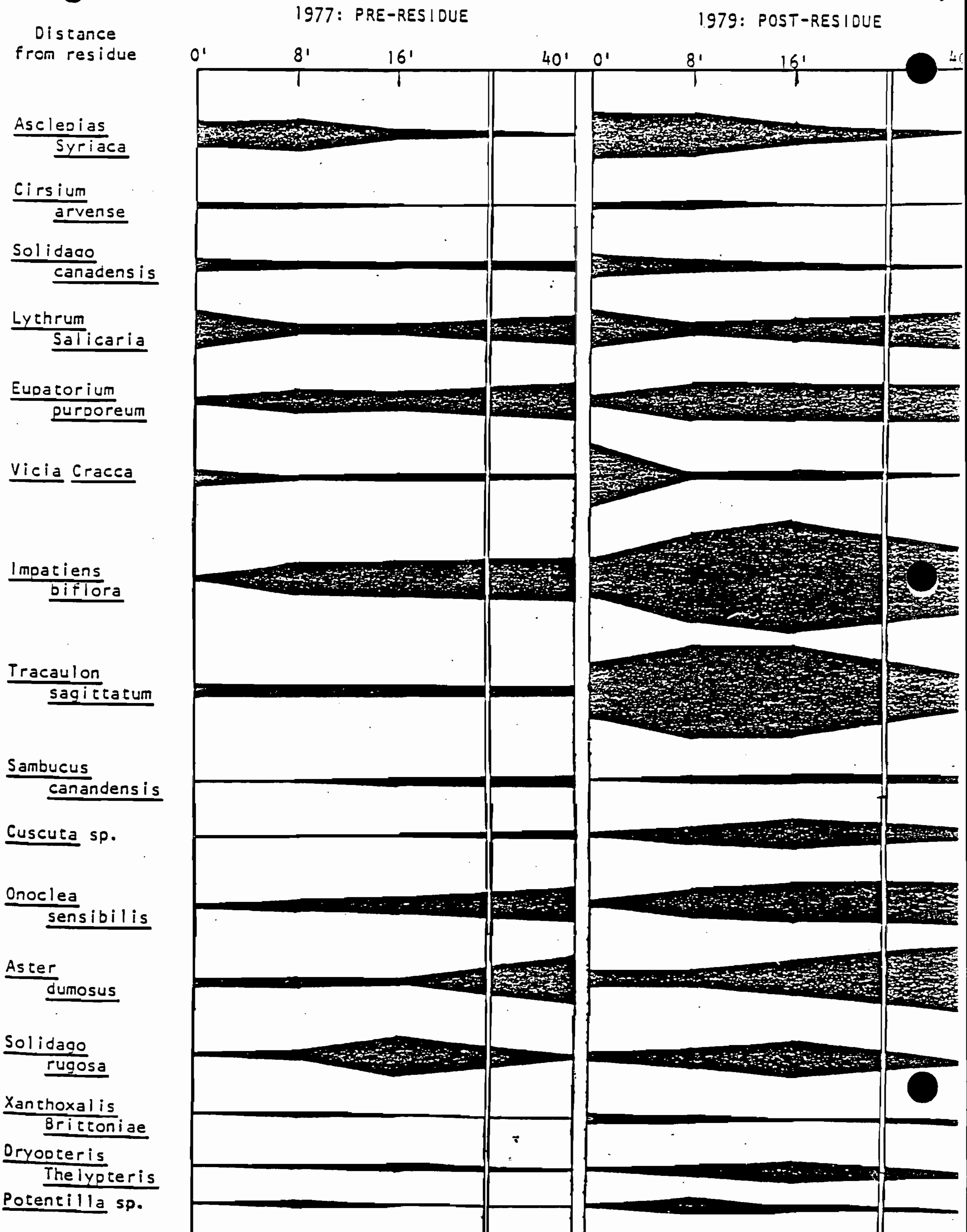

1977: PRE-RESIDUE
1979: POST-RESIDUE
Distance from residue
0'
8'
16'
40'
0'
8'
16'
Asclepias Syriaca
Cirsium arvense
Solidago canadensis
Lythrum Salicaria
Eupatorium purpureum
Vicia Cracca
Impatiens biflora
Tracaulon sagittatum
Sambucus canandensis
Cuscuta sp.
Onoclea sensibilis
Aster dumosus
Solidago rugosa
Xanthoxalis Brittoniae
Dryopteris Thelypteris
Potentilla sp.

Table 4. Wetland higher plant community parameters: pre-(1977) and post-(1979) residue landfill.

ROW	DISTANCE FROM RESIDUE	COMMUNITY PERCENT COVER 1/		SPECIES DENSITY 2/		DIVERSITY 3/	
		1977	1979	1977	1979	1977	1979
A	0m (0ft)	116.4	288.4***	4.2	6.4***	2.16	2.38
B	2.4m (8ft)	157.8	373.1***	5.0	7.3***	2.49	2.45
C	4.9m (16ft)	173.6	407.0***	5.3	7.5***	2.38	2.37
D	12.2m (40ft)	201.9	274.5*	4.4	5.6*	2.16	2.16

1/ Percent Cover = $\sum_{i}^{S} (\text{cover}_i / \text{cover}_T)$, where: i=species, 1,2,...S; cover_i=area occupied by species "i"; cover_T = total area

2/ Species Density = $\sum_{j}^{Q} (\#\ \text{species/quadrat}_j)/Q$, where: j=quadrat 1,2,...Q

3/ Diversity = H' = $-\sum_{i}^{S} P_i \ln P_i$, where: i=species 1,2,...S; P_i=percent cover for species "i"; ln=natural log function

* significant increase at .05

*** significant increase at .01

Table 5. Metal uptake of three plant genera growing on residue piles during summer, 1979. Pile "A" was deposited directly over existing groundcover; pile "B" was deposited in a 2 foot deep trench and brought up to grade. Data represent metal concentration in leaves, measured in parts per million (ppm).

	Pb	Cd	Zn	Ni	Cu	Cr	
<u>Lythrum Salicaria</u> collected 8/23/79	14	4.5	355	1.8	7.6	0.5	PILE "A"
"	10	3.0	525	1.9	4.3	0.3	PILE "B"
<u>Radicula</u> sp. collected 7/26/79	32	12	410	3.2	5.0	1.1	PILE "A"
"	41	22	850	4.6	6.0	1.0	PILE "B"
<u>Persecaria</u> sp. collected 7/26/79	18	0.90	115	1.8	6.0	0.8	PILE "A"
	23	0.28	310	2.9	5.0	0.7	PILE "B"

Soil Algae Studies

Sampling and Culture Techniques

Wetland soil algae were sampled one month (Series I), three months (Series II), 13 months (Series III) and 15 months (Series IV) following residue deposition. Soil samples were taken at distances of 0m (Row A), 2.4m (8 ft, Row B), 6.1m (20 ft, Row C) and 12.2m (40 ft, Row D) from the submerged residue along transects # 10, 11, 12 and 13 (see Figure 1). The soils were dried and graded according to particle size. Fifteen g of medium grade (1 mm) soil, covered by 10 g of fine grade (0.25 mm) soil from each wetland sampling location, were weighed into each of three petri plates. Soils were saturated with 20 ml sterilized, distilled water. Six # 1, 18 mm glass coverslips were randomly placed on the soil surfaces as algal collectors. The soil samples received continuous light at 21°C for a four week period.

At weekly intervals one coverslip was removed from each replicate for microscopic analysis. Determinations were made as to the percent cover (proportion of area occupied [an estimate of abundance]) and richness (number of algal types) of the algal communities. Identification was made to family, this being the lowest practical OTU (operational taxonomic unit) which could be identified without subculturing.

Data Analysis

Algal community data were grouped by distance and time from residue deposition. These groups contained data from Rows A, B, C, and D, (increasing distance from the residue), and Series I, II, III and IV, (increasing time from residue deposition).

Abundance of soil algae was estimated by determining the percent cover of algal communities during the third culture week. The systematic sampling procedure, described previously, necessitated the use of nonparametric statistics. The abundance data were tested for significant differences over distance and time using two nonparametric tests: 1) Kruskal-Wallis one-way ANOVA for samples and 2) Mann-Whitney U test for two samples. Significance was set at 0.05.

Richness of the algal communities was determined by totaling the cumulative number of algal families sampled during the four week culture period (Series) at each distance (Row) from the residue. Significant differences in richness were assessed as with abundance.

Results and Conclusions

The soil algae were classified into three divisions (Cyanophyta or "blue-green algae" [classified here as algae despite bacterial affinities], Chlorophyta or "green algae" and Chrysophyta or "golden-brown algae" [including only the Bacillariophyceae or "diatoms"]), ten orders and 14 families.

Abundance. The abundance of soil algae (as percent cover) over time and distance from residue deposition is presented in Figure 9. Chi square (X^2) values and associated probabilities signifying the significance of differences in abundance over distance and time are presented in Table 6. There were no significant differences in soil algal abundance over time, and only one significant difference ($0.02<p<0.05$) over distance which occurred in Series II (3 months following residue deposition). It is evident from Figure 3 that this difference resulted from the relatively high abundance in Row A (the residue/wetland interface). In general, as distance into the wetland increased, algal abundance varied less over time and tended to decrease. As time from residue deposition increased (Series I to Series IV), algal abundance varied less over distance. Therefore, with increasing time and distance from residue deposition, the variation in algal abundance decreased.

Richness. Richness of the soil algal communities over distance and time from residue deposition is presented in Figure 10. Chi square values and associated probabilities that signify the significance of differences in community richness are presented in Table 7. Over distance, the richness of algal communities differed significantly only during the first month following residue deposition. Over time, significant changes in richness occurred only midway (Row C) into the experimental area of the wetland. The data presented in Figure 10 indicate that these differences in community richness were attributable to a significant increase in algal types cultured from Row C (6.1m [20 ft] from residue) during Series III and IV. As with algal abundance, there appeared to be a trend toward increasing inter-row similarity with time.

A summary of the significant differences resulting from 2-sample testing (Mann-Whitney U test) of all row and series combinations is presented in Table 8. These results indicate the individual row and/or series data which contributed to the previously noted trends in abundance and richness. Significant differences in both abundance and richness among the rows (distance factor) occurred only during the first few months following residue deposition, and were the result of relatively high abundance and richness at the residue/wetland interface (Row A). Significant changes in algal parameters over time were due predominantly to an increase in algal types in Row C, and a decrease in algal abundance in Row A. There were no significant inter-row differences in year 2 (Series III and IV), and no significant inter-series differences in Rows B and D.

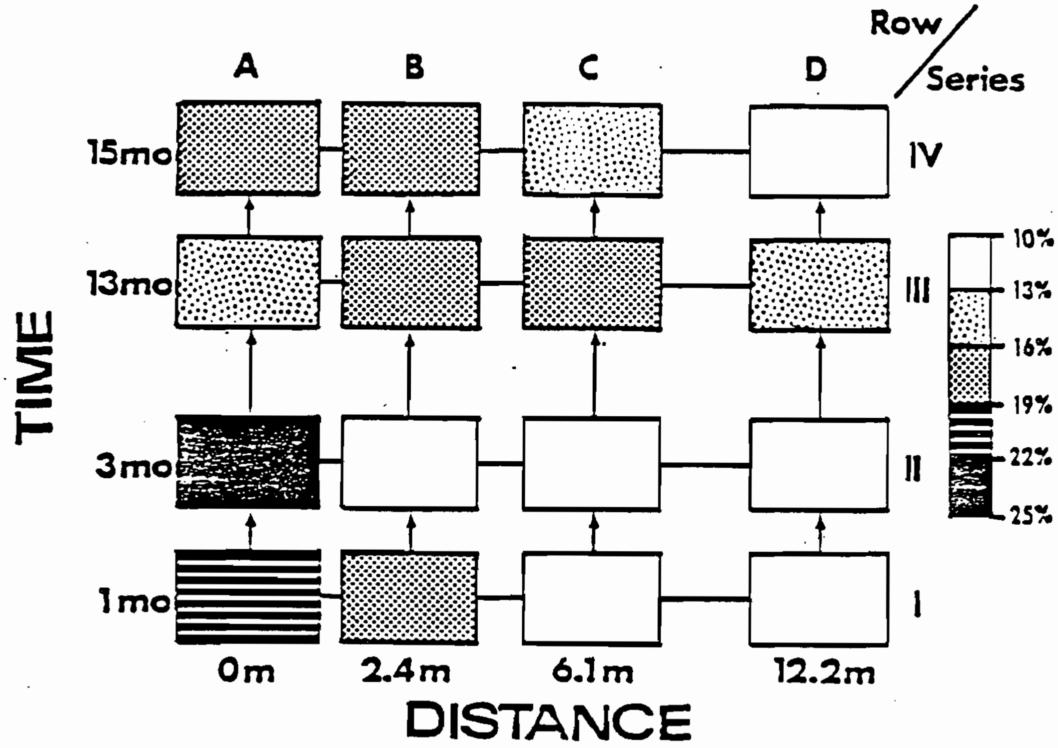
Soil lead levels proximate to the disposal site increased by approximately 25 ppm. If this influx of residue lead were available to the wetland soil algae, such quantities might be sufficient to disrupt this community of micro-algae whose metal tolerances are often measured at levels below 1 ppm. The hypotheses of declining algal abundance and/or community richness were not supported by the data collected from these high lead soils. Soil lead levels in both Rows A and B increased significantly over time, whereas algal abundance declined only in Row A. The change in algal abundance at the wetland border (Row A) was due to an initial increase in ephemeral algae (colonizing organisms) which would be expected following a nutritive salt influx from the residue and/or reduced competition following soil crust disturbance as a result of residue deposition. Therefore, the limited leaching of residue lead, and the lack of sufficient evidence of an adverse response in the soil algal community indicated that residue heavy metals had not leached in quantities sufficient to disturb soil algal community structure.

Heavy metal mobility and availability are both source-specific and site-specific. Though the heavy metal concentrations in incinerator residue are high, when land-applied, heavy metal impact depends less upon concentration than on chemical speciation and the physical and chemical nature of the soil. Testing procedures should therefore be designed so as not to overlook pollutant interactions in the soil.

Figure 9. Soil algal abundance as percent cover over time and distance from incinerator residue depostion.

Figure 10. Soil algal community richness over time and distance from incinerator residue deposition.

9


Row
Series
A
B
C
D
15mo
13mo
3mo
1mo
IV
III
II
I
TIME
0m
2.4m
6.1m
12.2m
DISTANCE
10%
13%
16%
19%
22%
25%

10

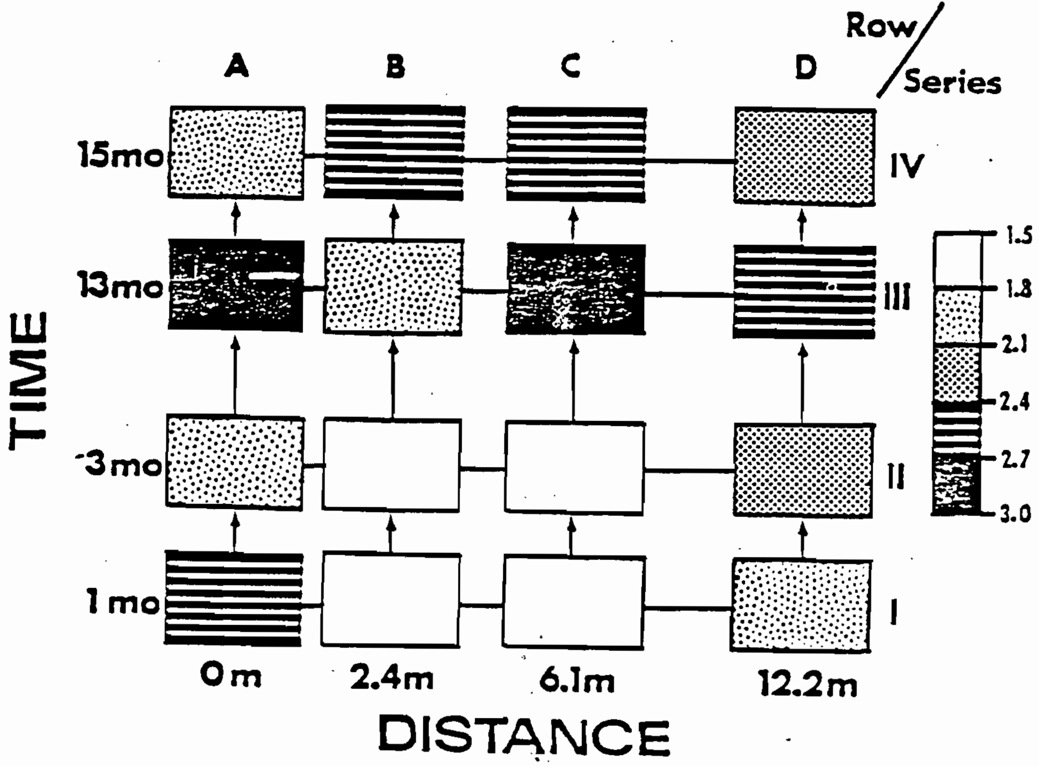

Row
Series
A
B
C
D
15mo
13mo
3mo
1 mo
IV
III
II
I
TIME
0m
2.4m
6.1m
12.2m
DISTANCE
1.5
1.8
2.1
2.4
2.7
3.0

Table 6. Kruska-Wallis one-way ANOVA of algal abundance (percent cover) over distance and time. Significant differences are indicated by one or more asterisks over the chi-square value (X^2). Associated probabilities are included in parentheses.

DISTANCE ANALYSES (Rows A to D)

Series I	$X^2 = 5.41$	$(0.10 < p < 0.20)$
Series II	$X^2 = 8.04$*	$(0.02 < p < 0.05)$
Series III	$X^2 = 1.47$	$(0.50 < p < 0.70)$
Series IV	$X^2 = 3.56$	$(0.30 < p < 0.50)$

TIME ANALYSES (Series I to IV)

Row A	$X^2 = 5.27$	$(0.10 < p < 0.20)$
Row B	$X^2 = 3.70$	$(0.20 < p < 0.30)$
Row C	$X^2 = 3.21$	$(0.30 < p < 0.50)$
Row D	$X^2 = 2.85$	$(0.30 < p < 0.50)$

*: significant difference at 0.05; df=3

Table 7. Kruskal-Wallis one-way ANOVA of community richness (# of families) over distance and time. Significant differences are indicated by one or more asterisks over the chi-square value (X^2). Associated probabilities are included in parentheses.

DISTANCE ANALYSES (Rows A to D)

Series I	$X^2 = 9.27$*	$(0.02 < p < 0.05)$
Series II	$X^2 = 5.06$	$(0.10 < p < 0.20)$
Series III	$X^2 = 4.00$	$(0.20 < p < 0.30)$
Series IV	$X^2 = 2.05$	$(0.50 < p < 0.70)$

TIME ANALYSES (Series I to IV)

Row A	$X^2 = 6.26$	$(p = 0.10)$
Row B	$X^2 = 2.41$	$(0.30 < p < 0.50)$
Row C	$X^2 = 12.18$***	$(0.001 < p < 0.01)$
Row D	$X^2 = 2.21$	$(0.50 < p < 0.70)$

*: significant difference at 0.05; df=3

***: significant difference at 0.01; df=3

Table 8. Summary of significant results from "2-sample" testing[a/] of algal community abundance and richness over time and distance from residue deposition.

SERIES (time from residue deposition)		ABUNDANCE[b/]	RICHNESS[c/]
I	(1 mo)	Row A: Row C*	Row A: Row B* Row A: Row C**
II	(3 mo)	Row A: Row B* Row A: Row C* Row A: Row D**	NSD
III	(13 mo)	NSD	NSD
IV	(15 mo)	NSD	NSD
ROW (distance from residue)			
A	(0 m)	Ser.II: Ser.III*	NSD
B	(2.4m)	NSD	NSD
C	(6.1m)	NSD	Ser.III: Ser.IV** Ser. I: Ser. IV* Ser.II: Ser.III** Ser.II: Ser. IV*
D	(12.2m)	NSD	NSD

a/: Mann/Whitney U test
b/: measured as percent cover
c/: number of algal families
NSD: no significant differences

*: significant difference at 0.05
**: significant difference at 0.02

Heavy metal toxicity is species-specific. The impact of potentially hazardous waste leachates on biota should be assessed on indigenous organisms. Soil algae provide a practical approach for investigating the potential and actual impact of waste leachates on terrestrial ecosystems.

Wetland/Residue Studies: Discussion

This research was designed to assess the impact of low-level, long-term heavy metal pollution on a wetland ecosystem. Environmental research on pollutant stress generally involves two types of effects: acute and chronic. Acute responses usually follow short-term exposure to lethal pollutant concentrations. The effects are easy to identify and quantify, either at the population or community level. To date, no acute effects of metal toxicity have been observed in the wetland.

According to the classification system devised by Smith, pollutant/ecosystem interactions may be designated as one of three types:

1) Class I includes interactions where soil and/or biota are unaffected sinks for pollutants;
2) Class II includes sublethal, adverse effects on organisms and/or processes; and
3) Class III includes lethal effects (acute) on organisms and the likely disruption of ecosystem processes.

In order to classify such interactions, the experiment must disclose the relative abundance, mobility, availability and toxicity of the pollutant. By examining both chemical and biological parameters, these studies were designed to assess the abundance, mobility, availability and toxicity of incinerator residue heavy metals, and the resultant pollutant/ecosystem interaction.

The site selected for the field experiment approximated "worst case" conditions for heavy metal leaching. Acid conditions tend to increase the mobility and availability of heavy metals. The residue was exposed not only to an acid soil/water substrate (pH range 4.8 - 5.2), but was also leached by acid precipitation (avg. pH 4.0). Recent evidence on the effects of "acid rain" has indicated that soils are the primary sink for excess acidity. Acid precipitation may, therefore, have a pronounced effect on heavy metal interactions in terrestrial ecosystems.

The combined data from soil and groundwater monitoring indicate that, 15 months following residue deposition, measurable quantities of metals had not leached from the residue, with the possible exception of lead. Given this information, the ecosystem/pollution interaction cannot be classified beyond Class I where the soil may be acting as an unaffected sink for lead.

Because there was not measurable heavy metal leaching from the residue (with the possible exception of lead), the biological availability of these metals and the levels necessary to disturb plant communities are still unknown. This lack of positive results in both the chemical and biological data, however, does indicate that in 15 months time, the incinerator residue has had no adverse effects on the wetland ecosystem. If the significant increase in soil lead at the wetland border (Row A) is the result of residue leaching, the lack of an adverse reaction in the biological community questions the availability or toxicity of incinerator residue lead in organic soils.

LEACHING STUDIES

Since all manner of solid wastes are burned in the incinerator, the residue contains a spectrum of heavy metals including Pb, Cd, Zn, Cu, Ni, Cr, Fe, Mg, and Mn Contamination of the soil, aquatic ecosystems, or the ground water by heavy metals leaching from the incinerator ash residue or products made with the residu would mean that the residue could not be marketed and also could not be used as landfill except in those few situations where it could be totally isolated from the surrounding environment. The problem appears to be further exacerbated by t fact that rain falling on the northeastern United States is highly acid in character. Acid precipitation could actually increase the rate of release of heavy metals from the residue since it is well documented that some heavy metals are more easily mobilized under increasingly acid conditions.

It is clear that unless the environmental impact of this material can be assesse and understood, no cogent, practical method of disposal and/or use of this residue can be made, and further, if the residue cannot be safely disposed of, no large-scale development of solid waste to energy planning or implementation can carried out.

These studies were undertaken to learn how the residue acid precipitation interaction would affect the leaching of heavy metals from the incinerator ash residue both in the presence and the absence of natural field soil.

Experimental Methods

Incinerator ash residue was obtained from the RESCO incinerator and brought to the Suburban Experiment Station of the University of Massachusetts in Waltham, Massachusetts. Lysimeters were constructed from 111 liter plastic trash cans by cutting a hole in the side 2 cm above the bottom of the can and inserting a piec of tygon tubing which, in turn, led into the shoulder of a 1.9 liter plastic (polyproylene) bottle with a cap. The bottom of the can was filled with 5 cm of styrofoam balls to provide unimpeded drainage through the drain spout. Duplicate lysimeters were filled with about 95 liters of pure RESCO incinerator ash r sidue. At a later date, an added series of lysimeters, constructed in the same manner, were filled with i) duplicate lots of unamended, unsterilized field soil and ii) mixtures of this field soil and incinerator ash residue. The complete experiment contained a pair of lysimeters with only incinerator ash residue, a second pair with only field soil, a third pair with field soil superimposed over ash, (S/A) and a fourth pair with ash superimposed above field soil. (A/S). In the mixed cans the bottom layer of soil or residue was 28 cm deep and the top layer was 43 cm deep. The filled cans were placed on cinder block platforms in the open air on a site which was not obstructed by trees or buildings. They were, therefore, exposed to each rainfall or snowfall event which occurred durin the period of the study. In addition, a rain gauge was installed on the same site so that rainfall could be measured and collected for chemical analysis. No water was added to any of the columns other than that which occurred as a natura rainfall or snowfall event. Any water leaching through the lysimeter columns wa collected immediately after each rainfall event and tested for pH and soluble sa Leachate from the paired lysimeters was combined and a sample was preserved by freezing until it could be analyzed chemically for a series of heavy metals, including Cd, Pb, Cr, Cu, Zn, & Ni. Some samples were also analyzed for Fe and Mn pH was measured with a PhotoVolt pH meter equipped with a combination electrode. The meter was calibrated before each series of measurements. Soluble salts were measured with a Lectro HO Meter distributed by LABLine. Measurements were recorded as umhos/cm. Heavy metal analyses of the water samples were made using a Perkin Elmer Atomic Absorption Spectrometer # 403 and all analyses were carried out by the Microanalysis Laboratory of the University of Massachusetts in Amherst, Massachusetts. (Signal/noise ratio for that instrument is about 2). Rainfall amounts were recorded in mm for each rainfall event. Ash residue analysis was carried out by digesting 5 grams of a thoroughly mixed larger sample dried at 90° C/72 hr and sieved through # 60 soil sieve. The material was covered with aqua regia and heated to near dryness. It was then cooled and weighed and enough 25% HNO_3 was added to bring the total weight gain to 25 grams. This mix was left standing over night after which it was stirred and filtered. The filtrate is a 5 times dilution of the original metal concentration. Analyses were made using an Atomic Absorption Spectrophotometer, Perkin Elmer # 403. These analyses were carried out by the Research Laboratory of the Commonwealth of Massachusetts Department of Public Works. Pure residue leaching columns were set up in Oct. 1978, the mixed S/A & A/S columns were set up in Nov. 1979 and sampling data continues to be collected to the present.

Results and Discussion

Acid soluble metal ion concentrations of the incinerator ash residue used in these studies are given in Table 9. The parent material is quite heterogeneous which gives rise to some of the differences in concentration between samples. Quantity and pH of the rainfall events are shown in Table 10. The average pH for rain and snow events recorded from 1978 to the present was 4.0. Normal rainfall pH is considered to be about 5.3 - 5.6, which means that rainfall recorded in this study should be characterized as acid precipitation. In 4 weeks soluble salt levels in the pure ash lysimeter leachate dropped from 2500 umhos to below 20 umhos. Total rainfall passing through the pure ash columns totaled 360,000 ml as of June, 1981. Rainfall passing through the mixed columns totaled 36,000 ml as of the same date. pH of the pure ash leachate ranged from 7.6 - 8.2 and averaged about 7.9. pH of the soil leachate ranged from 5.8 - 7.1 and averaged 6.4; while that of the soil over ash mix ranged from 7.5 - 8.2 and averaged 7.9; and ash over soil ranged from 5.7 - 7.7 and averaged 6.7. These figures represent a total rainfall of 60 inches for the period in question.

Table 11 shows the mean concentration of heavy metals in leachate collected from all the columns during separate rainfall events extending over a period of 33 months. Table 12 shows the results of sampling a single rainfall event in September 1980. Here leachate from all the possible combinations was analyzed along with rainfall taken during the same event.

Rainfall events during the entire experimental period consistently produced rain with a pH of about 4.0. Leachate from the "Ash only" columns has continued to have a mean pH value of about 7.9, indicating the high exchange capacity of the incinerator ash residue. The mechanisms responsible for this effect are not yet understood but the effect is remarkable for its persistance over time. Soluble salts like Na, K, etc are apparently leached out very rapidly as indicated by the measured changes in electrical conductivity over time. The high "heavy metal" content of the remaining ash residue does not reveal itself in the leachate during the 33 months experimental period. Heavy metal content of the ash residue leachate is about the same as that found in the ambient rainfall during the 33 month observation period. This could be due to the basic physical/chemical composition of the residue resulting from the previous high temperature treatment. The heavy metals were simply tied up

Table 9. Acid soluble metal ion concentrations in incinerator ash residue samples

Metal ions ppm	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5
Cd	32.2	32.0	29.7	28.0	34.3
Pb	3503	3635	3499	3015	4321
Cr	98.7	128	115	116	137
Ni	113	148	134	172	147
Al	1.98%	2.45%	2.50%	2.00%	2.15%
Cu	1610	899	633	3490	773
Mn	.388%	3.89%	.405%	.419%	.394%
Zn	2.25%	2.21%	2.01%	3.55%	2.47%
Fe	6.52%	6.47%	6.41%	7.63%	6.31%
Ca	1.96%	1.90%	2.12%	2.10%	1.82%
Na	2.81%	2.67%	2.86%	2.59%	2.34%
Mg	.297%	.290%	.311%	.359%	.308%
K	.356%	.396%	.418%	.404%	.369%

Table 10. Total amount of rainfall passing through leaching columns over 33 months and mean pH of that rainfall before and after passing through leaching columns made up of ash residue, soil, and mixtures of ash residue and soil.

Type of Leaching Column	Total Amount of Rainfall Passing through Leaching Columns	pH of Rainfall (Mean)	pH Leachate Water (Mean)
Ash	360,000 ml*	4.0	7.9
Soil	36,000 ml	4.0	6.4
Soil over Ash	36,000 ml	4.0	7.9
Ash over Soil	36,000 ml	4.0	6.7

* Total Rainfall for 33 months = 60 inches

Table 11. Mean heavy metal content in all leachates over 33 months. (all values are ppm)

	Pb	Ni	Cd	Cu	Cr	Zn
Residue	0.18	0.07	0.006	0.027	0.037	0.07
Soil	0.19	0.03	0.006	0.03	0.035	0.05
Residue/Soil	0.32	0.04	0.006	0.025	0.035	0.075
Soil/Residue	0.375	0.07	0.008	0.025	0.035	0.105
Rain	0.173	0.038	0.013	0.023	0.03	0.05

Table 12. Heavy metal content of leachate from all columns taken during a single rainfall event in September 1980

	Metal Ions in uq/ml					
Column Identification	Pb	Cd	Ni	Cr	Cu	Zn
Ash only	0.14	<0.005	0.04	<0.04	<0.01	0.02
Soil only	0.21	<0.005	0.04	<0.04	0.03	0.05
Soil over Ash	0.53	0.010	0.12	<0.04	0.02	0.11
Ash over Soil	0.42	<0.005	0.06	<0.04	0.02	0,06
Rain only	<0.14	<0.005	<0.04	<0.04	<0.01	0.02

Rain only pH = 4.0

in non-active forms by the heat treatment and are therefore not reactive even when leached with water carrying a pH of 4. It is also possible that the ability of the ash to raise the pH of the incident rainfall which leaches through it, makes it less vulnerable to a loss of heavy metals which might normally be released if leached with water carrying a pH of 4. At this point it is not possible to say which of these mechanisms is more important or if both may be operative.

Based on this simplest case it would seem reasonable to describe the incinerator bottom ash residue as a relatively benign material which would not release its heavy metal load into the environment when leached with acid precipitation. The demonstrated ability of the ash to attract and hold hydrogen ions also suggests that the material might be used to cover older dump sites and landfills in order to raise the pH of the rainfall leaching through these sites thus possibly reducing the rate of heavy metal leaching from the metal sources buried in the sites. However, such a prospect must be viewed with great caution because soil in the presence of ash in the leaching columns may foster a different kind or rate of chemical behavior than that found in the pure ash.

HORTICULTURAL STUDIES

Horticultural applications of RESCO ash residue could provide an attractive market for this material. To this end, several different demonstration projects were initiated and carried out at the Suburban Experiment Station of the University of Massachusetts in Waltham, MA (SES).

Greenhouse Raised Benches

RESCO residue was used to fill several raised concrete benches in an experimental greenhouse range at SES in 1976. Over the years since then these benches have been used to grow a variety of different plant species. The initial pH and soluble salts in these residue beds was 8.9 and over 2,000 respectively. Flooding of the beds wi tap water (pH 8.2) once a week for 3 weeks reduced the pH of the residue to between 7.2 - 7.5 and the soluble salts to below 100. The beds were then sown with annual and perennial rye grasses and watered on a weekly basis. No fertilizer was added f 3 months and the result was a good, green grass cover as shown in Fig. 11. The demonstration showed that the bare residue with no soil cover could support good plan growth and that there was some amount of available plant nutrient in the residue which leached out or was used up within a few months, after which time it was necessary to routinely fertilize the plots.

In subsequent studies these beds have supported such diverse crops as lettuce, corn tobacco, geraniums, marigolds, zinnias, petunias, chrysanthemums, narcissus, a[illegible] daffodils. All plants grew normally on the residue, produced normal flowers, [illegible]it and seed where applicable. (Figures 12, 13, and 14).

Another study utilized one of the beds to demonstrate the feasibility of using RESC residue as cover for a roadside slope along a highway. Fig. 15. The bed was set up to provide a "hill" of residue which sloped down to a lower level soil surface. The hill and soil were seeded with rye grasses and fertilized and watered on a routine basis. It was found that grass grew equally well on the residue hillside and on the soil below. Further, soil analysis showed that any heavy metals leaching out of the residue did not flow down the slope into the soil below, but leached vertically directly down through the ash hill and accumulated at the bottom of the ash hill but not in the adjacent soil. Heavy metal leaching was minimal and well within RCRA standards. These results are further evidence of the utility of the RESCO residue as a useful horticultural tool.

Turf Plot

A series of turf demonstration plots are routinely maintained on the grounds of SES. These were seeded in 1975 to demonstrate the performance of cool season grasses suited to eastern Massachusetts. There were 12 plots which measure 20 X 50 feet and are bisected by sun and shade. Grass varieties were selected for their availability in local garden centers. Maintenance consists of a weekly mowing at a height of 2-1 inches and normal fertilizing and liming schedule. In 1976 a 13th plot was added which was prepared with RESCO ash residue as the subsoil layer. A ten inch dee[illegible]bec was dug adjacent to the other turf plots. The bottom 6 inches were filled wit RESCO ash residue and this sub-layer was covered with 4 inches of native topsoil fro the SES grounds. The plot was graded, seeded, fertilized, compacted and watered. From then on it was treated exactly the same as the other 12 adjacent plots. Growth

Figure 11. Annual and perennial turf grasses growing on RESCO incinerator ash residue.

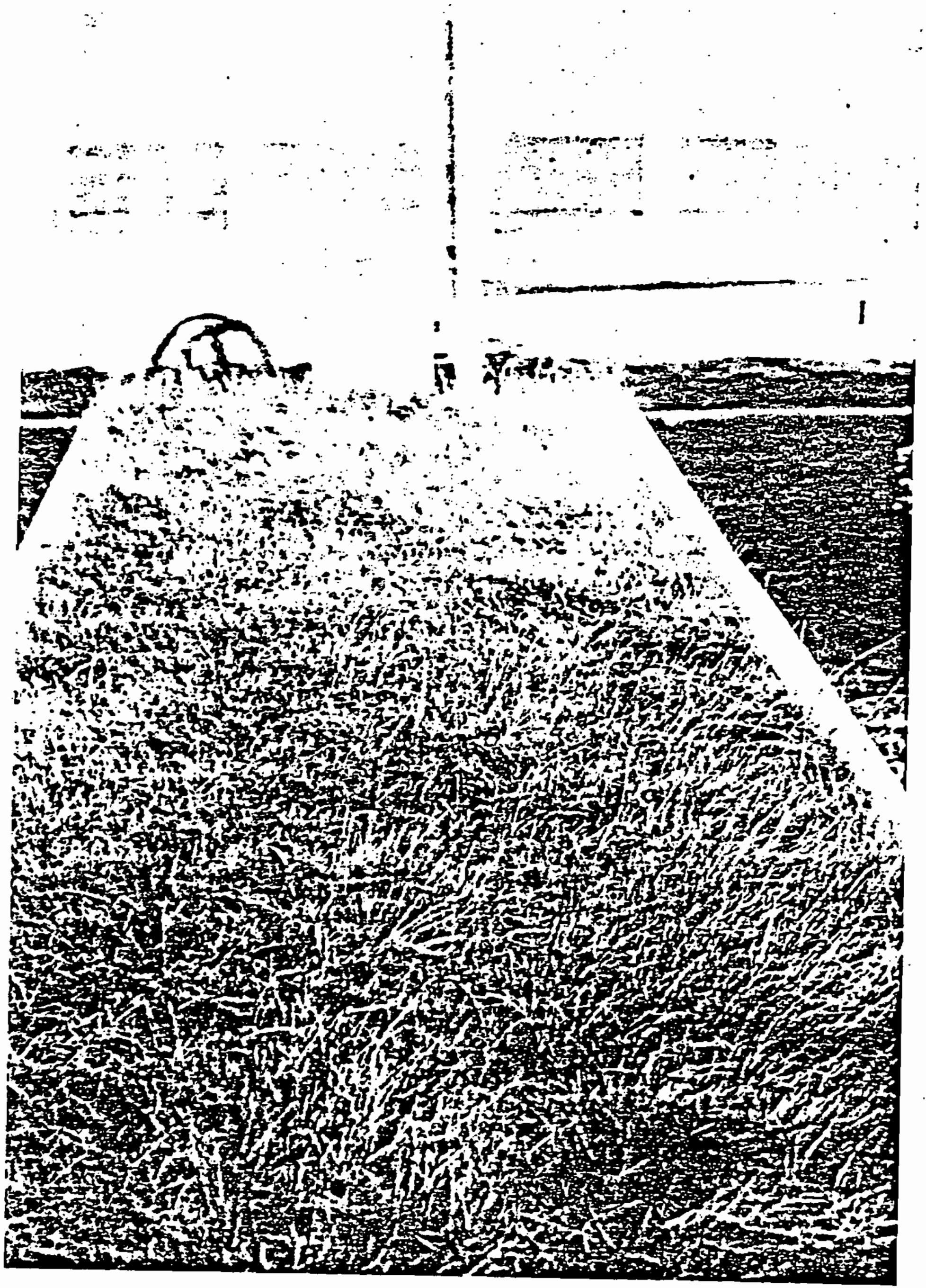
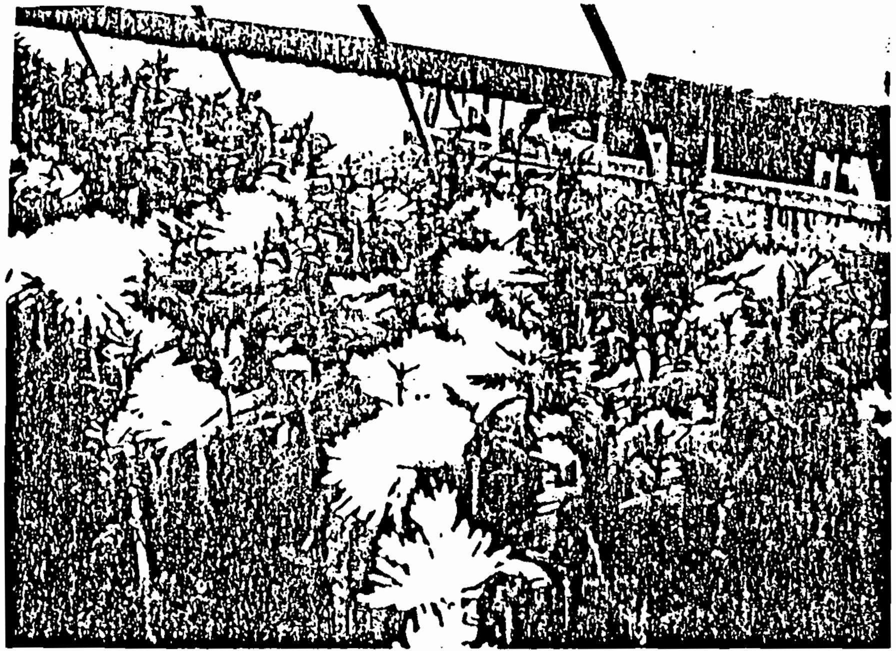
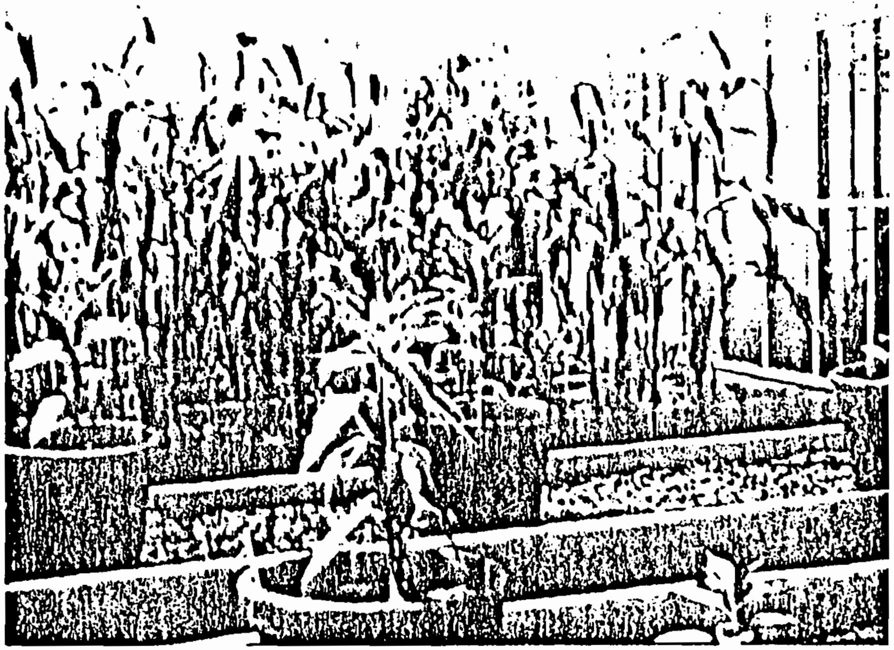
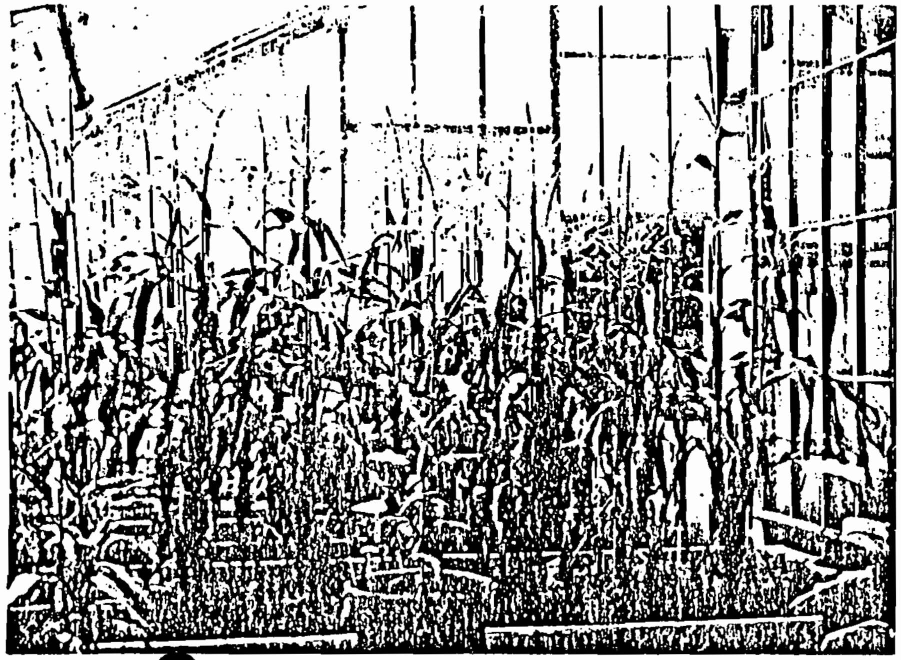


Figure 12. Begonia, Coleus, Chrysanthemum and flowering bulb cultivars growing in RESCO incinerator ash residue.







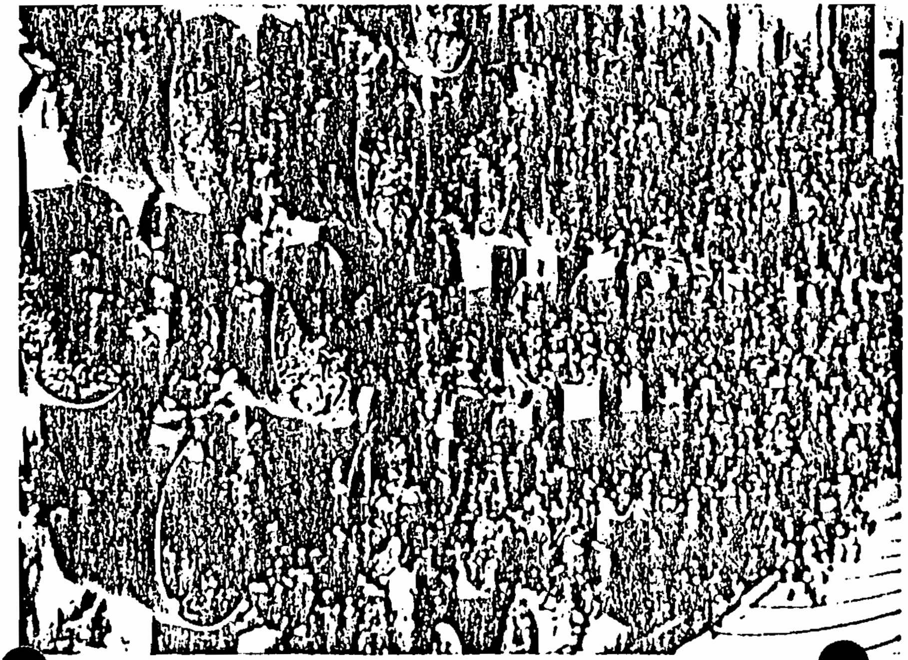
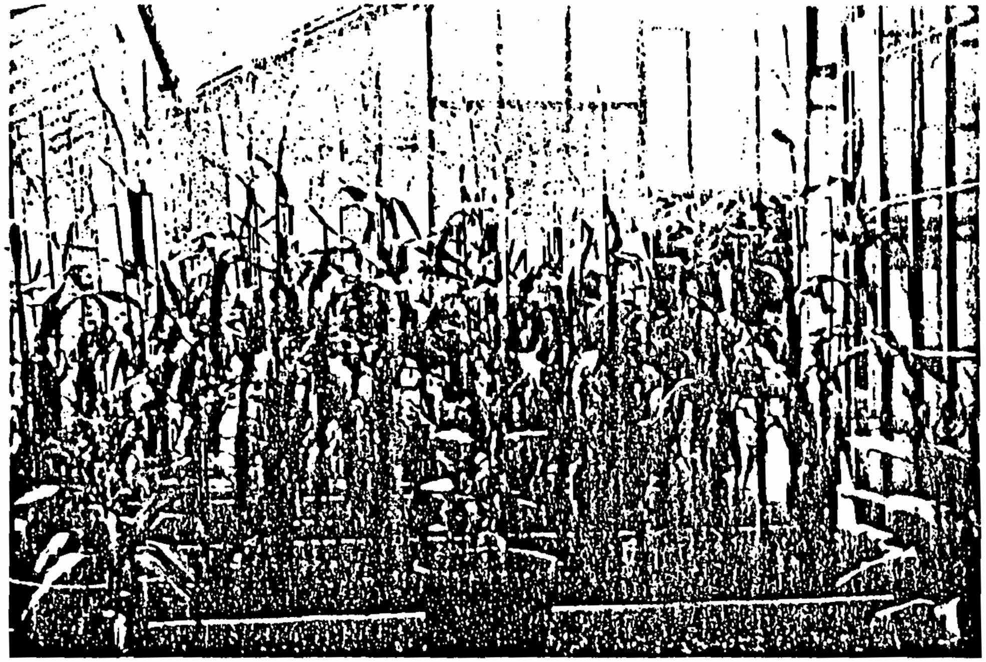
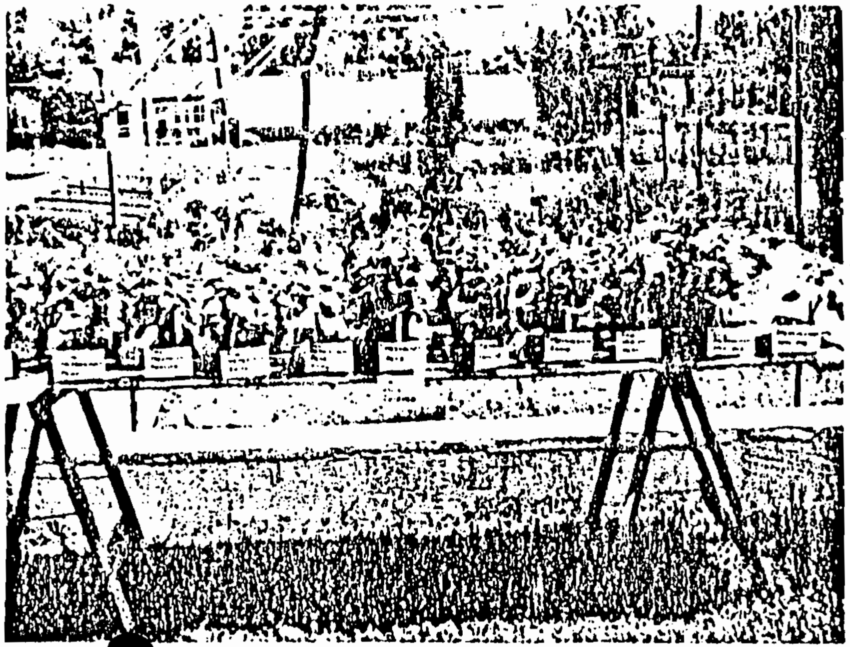


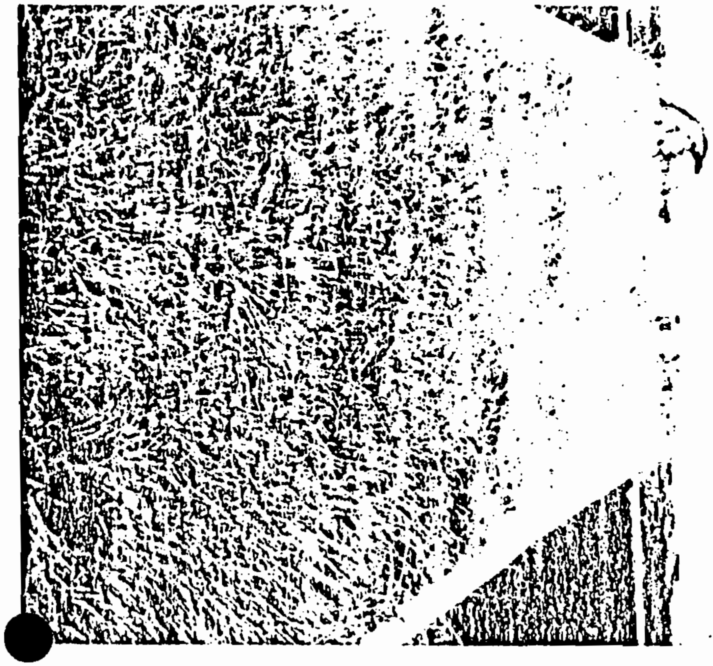
Figure 13. Field corn growing in RESCO incinerator residue.

Figure 14. Geraniums growing in RESCO incinerator residue.

Figure 15. Grass growing in RESCO incinerator residue in "Roadside" simulation study.







and development of grass on this plot has been normal and the turf surface seems to be able to withstand wear and compaction quite well. Subsoil drainage under the pl is excellent and fertilizer response has been normal. The results indicate that th RESCO residue might prove useful as a subsoil material for the landscaping industry and for the construction of golf course greens and fairways.

Pot Studies

Another possible horticultural use of the RESCO residue is as a potting mix for plants like Poinsettia, Begonia, Chrysanthemum, Geranium etc. Several demonstratio studies were carried out with these different commercially important plant species in order to evaluate the RESCO residue as a soil medium in pot culture. Since thes plant types are all non-edible and are only used decoratively, there is little concern for the heavy metal content of the residue except for the possible effect it may have on plant growth and development. The basic format was the same for all th pot studies. Residue, residue and mixtures of peat or Perlite plus soil in various mixture ratios, and soil alone were the media used throughout. Commercially rooted cuttings of Poinsettia, Chrysanthemum, Begonia, and Geranium were used in all cases Growing conditions and cultural practices were kept as close to commercial practice as possible. All tests were run in a greenhouse during the winter heating season; i.e.: November through March. All plants were grown to maturity and data was collected periodically in order to record possible changes or differences in plant gro vigor, flower production, time to maturity etc. In addition, some data measuring heavy metal uptake in plant materials was also recorded. The results of these studies may be seen in Table 13, 14.

In summary, these results indicate that the RESCO residue can be used as a medium for raising pot plants. The residue drains very well but is quite heavy. This makes the pot and its contents quite heavy; a factor which would be considered disadvantageous from a labor point of view. Planting, cultivation, water and pest con trol are all equally as good in residue as in a good commercial soil mix. Plant re sponse to residue differs among species and may differ among individual cultivars (varieties) of the same plant species. Chrysanthemums and Geraniums grow as well i residue as in soil; Poinsettias and Begonias do less well as the proportion of resi due to soil is increased. However, all of these plant species will produce a commercially acceptable crop in the RESCO residue. Figs. 14, 15. Uptake of heavy metals by several of the studies plant species as is shown in Table 13 indicate tha very little of the heavy metal load in the RESCO residue is in an "available" form; a further indication of the relatively benign nature of the RESCO residue.

Table 13. Pot plant studies using various mixtures of RESCO Ash Residue and soil and/or peat.

	Poinsettia			Begonia			Chrysanthemum			Geranium		
Growing Medium	Growth Rate	Vigor	Commercial Rating	Growth Rate	Vigor	Commercial Rating	Growth Rate	Vigor	Commercial Rating	Growth Rate	Vigor	Commercial Rating
RESCO RESIDUE	G	F	F	F	F	F	G	G	G	G	G	G
RESCO RESIDUE + Soil												
1/1	G	G	F	F	F	F	G	G	G	G	G	G
2/1	G	G	F	F	F	F	G	G	G	G	G	G
1/2	G	G	G	G	G	F	G	G	G	G	G	G
RESCO RESIDUE + Peat												
1/1	G	G	G	F	F	F	G	G	G	G	G	G
2/1	G	G	G	F	F	F	G	G	G	G	G	G
1/2	G	G	G	G	G	G	G	G	G	G	G	G
Standard Soil Mix (Control)	G	G	G	G	G	G	G	G	G	G	G	G

Ratings:

Growth Rate: Good(g); Fair(f); Poor(p)
Vigor: Good(g); Fair(f); Poor(p)
Commercial Rating: Good(g); Fair(f); Poor(p)

Table 14. Uptake of heavy metals in selected plant species growing on RESCO ash residue.

	Pb	Cd	Zn	Cr	Cu	Ni
Grass Leaves	33	0.95	127	1.1	35	8.3
Poinsettia						
Leaves	50	1.3	108	--*	--	--
Bracts	14	0.6	45	--	--	--
Geranium						
Tops (stems & leaves)	46	0.9	154	3.1	26	6.1
Chrysanthemum	26	4.4	248	2.6	16.3	4.8
Ash residue	3595	31	2620	119	1481	143

*Not analyzed

SUMMARY AND RECOMMENDATIONS

Studies carried on at the Suburban Experiment Station over the past 4 years with RESCO ash residue have indicated that land application of this heterogeneous material has had no discernable impact upon the quality of groundwater, the growth and diversity of the soil algal community, or the growth and diversity of the terrestrial higher plant community. Further, with the possible exception of Pb, ther has been no significant increase in heavy metal content of soils adjacent to large deposits of residue under our field conditions. Extensive leaching studies with natural rain have revealed no significant losses of heavy metals from the residue in spite of a mean rainfall pH of 4.0. The residue has a high buffering capacity which has persisted undiminished for over 3 years; during which time about 360,000 ml (60 inches) of pH 4.0 rainfall has passed through the residue. Under field conditions, the bare residue is readily colonized by native plant species, without the addition of any nutritional amendments. Three years after land application of the residue, the majority of the higher plants growing on the residue appear vigorous and normal. Some heavy metal uptake occurs in plants growing on the residue, but except for perennial plants, the amounts are not phytotoxic. Food chain contamination remains an area for study, but would be of no consequence to human consumption, since only non-food plants would ever be recommended for growth on the residue. The RESCO residue is an excellent medium for growth of turf and horticulturally valuable plant materials such as bedding and pot plants like chrysanthemums, poinsettias, geraniums, bulb plants etc. Mixtures containing RESCO residue, peat, and soil perform as well as commercial soil mixes and several soilles potting media. RESCO residue will also perform well as a subsoil for building golf courses and as fill for grading highway slopes and median strips. After [illegible] years' contact with soil and cropping with a variety of plants, the RESCO residue takes on the character of a loose, granular soil-like material which drains well, is easy to work, and is quite resistant to erosion from wind or water.

All the data to date indicate that the RESCO residue is a relatively benign materi which over the short-term will not release its heavy metal load into the environment when exposed to leaching with naturally occurring acid rains carrying a pH of 4.0. The demonstrated ability of the ash residue to attract and hold hydrogen ion also suggests that the material might be used to cover old dump sites and landfill in order to raise the pH of the rainfall passing through these sites thus possibly reducing the rate of heavy metal leaching from metal sources buried in the sites.

It must be born in mind that in terms of environmental change, 3-4 years is a very short period. Long-term (10-25-100) years of weathering of this ash residue may indeed begin to release significant amounts of heavy metals into the environment.

In order to best avoid further contamination of the environment (i.e. groundwater or biota), it is essential that the wetland studies at Waltham and Harold Parker State Forest, and the leaching studies described herein, be continued for at least 5 more years. The status of these projects will be updated on a yearly basis for that 5 year period.

A SUMMARY OF WORK COMPLETED AND OBSERVATIONS TO DATE

INCINERATOR RESIDUE - A COMPONENT OF BITUMINOUS PAVEMENTS

During the Summer of 1980, the Massachusetts Department of Public Works in cooperation with the Massachusetts Department of Environmental Management (Bureau of Solid Waste) and Refuse Energy Systems Company (RESCO) of Saugus placed a test pavement on Route 129 in Lynn, Massachusetts in which aggregate components of the bituminous pavement consisted, in part, of incinerator residue.

The incinerator residue used was the residue resulting from the incineration of municipal waste at the RESCO plant in Saugus.

Prior to the placement of the test pavement, preliminary laboratory evaluation and testing of the incinerator residue was performed. Based on the laboratory data obtained, various mix designs of asphaltic concrete incorporating incinerator residue as an aggregate component were developed and trial batches of mix were made and subject to standard test procedures.

As the resulting laboratory data indicated that the potential for using incinerator residue as an aggregate in bituminous concrete was promising, it was decided to place a test pavement in order to study all placement characteristics and service performance under actual field conditions.

The site selected for the test pavement was a section of Route 129 in Lynn. This highway met all of the criteria required in the work plan for this project.

The project as advertised included the placement of a bituminous concrete pavement consisting of four experimental sections that incorporated incinerator residue as aggregate in the bituminous paving mix and one control section of standard bituminous paving mix.

The contract was awarded to the Essex Bituminous Concrete Corporation. Work on placement of the first experimental section started August 16, 1980. This section was placed in two courses; 1-1/2 inch binder course and 1-1/2 inch top course. Each course was to consist of 100% incinerator residue plus asphalt. The binder course to consist of incinerator residue with maximum particle size of 1 inch and the top course with maximum particle size of 1/2 inch.

Only one lane 13 feet wide and approximately 1100 feet long was placed when production was halted because of plant break down. The plant operators, unfamiliar with incinerator residue were attempting to maintain their normal production rate. However, when only 120 tons of mix had been produced the breakdown occurred. To quote the plant owner "The air pollution equipment (baghouse collector) cound not handle the combination of a large percentage of super fine dust/ash and the high moisture content of the materials. The moist dust/ash caked up on the screw conveyor causing it to jam and burn out the drive motor".

After cleaning out the baghouse and replacing, the motor production resumed but after only another fifty tons were produced the same breakdown occurred again. At that point all work was cancelled for the day.

When work was resumed the following week, it was decided to discontinue any further attempts to place mix containing 100% incinerator residue as the aggregate. The remainder of this experimental section was paved with standard mix.

By reducing their production rate the plant operators were able to complete the remaining three experimental sections as stipulated in the work plan.

The paving mix containing the incinerator residue was prepared, placed and compacted with conventional equipment and standard methods. All pavements were open to traffic within the same time frame as with standard pavements.

With the exception of Section 4 all other experimental sections received a wearing course of standard top mix. The wearing course of Section 4 was a combination of 50% incinerator residue and 50% 3/8 inch natural aggregate. After exposure to traffic for a few days, particles of glass, pottery, metal and other reflective materials would sparkle and glitter under the sunlight or headlights at night. Other than this there were no other visually apparent differences between this section of pavement and the standard pavement.

Several weeks after all pavement sections had been placed and opened to traffic skid resistance tests were run on all experimental and control sections. Skid test results obtained on the section that contained incinerator residue in the wearing surface were comparable to the results obtained from the sections that had standard pavement for a wearing surface. A year later skid resistance tests were repeated and the results between experimental sections and control sections were still comparable. There was a small reduction in skid numbers but it was approximately the same between all sections of pavement.

To date this experimental project has been subject to the climatic extremes of two New England winters and at this point in time there does not appear to be any apparent difference in rideability, skid resistance or serviceability between the experimental sections and the control sections. However, it is too soon to draw any conclusive judgements regarding the suitability of incinerator residue and a substitute for natural aggregate.

Gene Bastanza
Research and Materials Section
State Department of Public Works
Commonwealth of Massachusetts

February 1982

COMMONWEALTH OF MASSACHUSETTS
DEPARTMENT OF PUBLIC WORKS
RESEARCH AND MATERIALS SECION
WELLESLEY HILLS, MASSACHUSETTS 02181

PROPOSAL
RESEARCH PROJECT R-37-0
BOTTOM ASH RESIDUE - A COMPONENT OF BITUMINOUS PAVEMENTS

Work Plan for Calendar Years 1979 - 1984

In cooperation with the Bureau of Solid Waste Disposal, Massachusetts Department of Environmental Management; Federal Highway Administration, U.S. Department of Transportation; and Resco, Inc. Saugus, Massachusetts

Submitted by
Gino J. Bastanza
Project Supervisor

R-37-0 Bottom Ash Residue - A component of Bituminous Pavements

The construction, restoration, and maintenance of highways consume vast quantities of natural resources, the supply of which, in many instances is rapidly diminishing. For example, the demand for aggregates is increasing at a time when sources near urban and other high-use areas are being depleted, and the quality of available aggregates is either at a low level or unavailable because of environmental restrictions and appreciating land values. Real and artificial shortages are therefore occuring.

Rising construction costs in an era of strong inflationary pressures, intense competition for available public funds, and increasing public demands to reduce the taxes which provide these funds, compel transportation agencies to develop and apply technologies aimed at curtailing the use of scarce or expensive materials and promote the use of less costly, more plentiful items. Reducing costs can be accomplished by the substitution of less expensive materials for those that are more costly. Today, municipal waste is being viewed as the largest source of material that may prove to be a cheap and abundant highways construction material.

Conservation of energy is a matter of growing national concern and importance. The substantial energy consumption in constructing highways provides an opportunity for energy conservation. The production of pavement aggregate requires energy for removal from their source, crushing, sizing, and transporting. Hauling aggregate can consume large quantities of energy to match distribution and quality of supply with project location. The result is that aggregate that is normally inexpensive can become costly from an energy viewpoint.

The objectives, as detailed above, can be identified as: (1) conservation of construction materials; (2) reduction of construction costs; and (3) energy conservation.

Limited research to date has indicated that one of the most promising and potentially valuable means of serving these needs lies in the use of incinerator residue (bottom ash) as an aggregate in bituminous pavement. The proposed state-wide network of seven regional resources recovery facilities in Massachusetts for the processing of municipal wastes will produce vast quantities of incinerator residue. An experimental construction project to examine the suitability of this residue as a substitute for asphalt concrete aggregate is therefore intended. This project will be financed with Federal and construction funds. Preconstruction engineering, monitoring and evaluation activities will be conducted as an HPR-II research study. A successful conclusion of this effort will also reduce land fill requirements for the disposal of waste material and demonstrate a beneficial environmental affect of the highway program

Research Objective:

To evaluate the feasibility, both technically and economically, of using incinerator bottom ash residue as a substitute for natural aggregates in plant mixed bituminous concrete paving mixtures.

Scope and Approach:

A. Select a highway that is currently under consideration for resurfacing and meets the following criteria:

1. There are no foundation or drainage problems
2. The profile and cross section are reasonably the same as original design, requiring only a minimum of leveling.
3. The ADT is a minimum of 15,000 including a reasonable amoun of truck traffic.
4. Project length is approximately 1.5 miles

B. Prepare a contract for pavement resurfacing including all Department standard design and construction procedures plus the following:

1. Divide the project length into five equal sections:

   Section 1 will be the control section resurfaced with 1-1/2" of standard I-1 binder and 1" of standard I-1 top.

   Section 2 will be resurfaced with 1-1/2" of binder mix (consisiting of a blend of 3/4" natural aggregate and bottom ash)plus 1" of standard I-1 top.

   Section 3 will be resurfaced with 2-1/2" of binder mix consisting of a blend of 3/4" natural aggregate and bottom ash. It will be sealed with rubberized asphalt and chip-stone.

The Commonwealth of Massachusetts
Department of Environmental Quality Engineering
Metropolitan Boston - Northeast Region
323 New Boston Street, Woburn, MA 01801

ANTHONY D. CORTESE, Sc.D.
Commissioner
727-5194

STATUS REPORT
RESCO ASH RESIDUE
ENVIRONMENTAL EVALUATION
DECEMBER, 1982

PREPARED FOR:

William J. St. Hilaire, P.E. WSH
Regional Environmental Engineer
Metropolitan Boston/Northeast Region

William F. Cass, Director
Division of Hazardous Waste

PREPARED BY:

John J. Fitzgerald
Senior Sanitary Engineer
Metropolitan Boston/Northeast
Region

Section 4 will be resurfaced with 1-1/2" of binder mix consisting of a blend of 3/4" natural aggregate and bottom ash plus 1" of top mix consisting of a blend of 3/8"natural aggregate and bottom ash.

Section 5 will be resurfaced with 1-1/2" of binder mix consisting of 100% bottom ash plus 1" of top mix consisting of 100% bottom ash. Depending on compaction results and surface texture, the Engineer will reserve the right to seal this section with rubberized asphalt and chipstone if he deems it necessary.

All work outlined above will be executed in accordance with Department standards and any contract special provisions.

C. As the contract progresses, monitor and document each of the following phases of the work:

1. Design and batching of bottom ash pavement mixes:
    a. Mix design criteria
    b. Problems, if any, of processing material through batching plant
    c. Any special treatment or handling of bottom ash residues
2. Placing and compacting the mix:
    a. Workability and placing characteristics of the mix.
    b. Irregularities, if any, in mix after passing through paving machine.
    c. Rolling characteristics of mix during compaction.
    d. Types of rollers and number of passes (Vibratory rollers will not be permitted)

3. Pavement Density:

   a. In-place density of the fininshed pavement course (both top and binder) will be determined by nucle density gage.

4. Finished pavement characteristics:

   a. Skid resistance

   b. Rideability

   c. Overall appearance and surface texture

5. Comparative service performance of finished pavement sections over a five year period:

   a. Semi-annual change in skid resistance properties

   b. Semi-annual change in rideability characteristics

   c. Semi-annual change in pavement durability - crac ravelling, rutting, shoving. etc.

Staffing

Francis W. Holden, Research and Materials Engineer

Gino J. Bastanza, Chief-of-Laboratory-Project Supervi

Joseph M. Hegarty, Pavement Maintenance Engineer-Proj
Technical Advisor

John L. Griffith, Principal Sanitary Engineer (BSWD)-
Project Coordinator

The environmental impacts associated with the handling, disposal, and/or re-use of the RESCO ash residue has been of continuing interest to the Department since operations began in 1975. Due to the lack of a comparable precedent and the nature and magnitude of the RESCO project, a series of laboratory and in-situ ash residue testing and analyses programs were instituted by facility operators and various agencies and institutions of the Commonwealth, including the Department of Environmental Quality Engineering, the Department of Environmental Management, and the University of Massachusetts.

In the intervening years, a considerable amount of analytical test data has been generated concerning the occurrence and leachability of metals and other inorganics in the ash residue. In recent months, however, concern in this area has increased dramatically, owing to an increased regional and national interest in resource recovery technology and the recent promulgation of state and federal solid/hazardous waste laws and regulations.

Ash Residue from the RESCO facility,approximately 200 tons per day, is currently being stockpiled on-site on the northwest perimeter of an abandoned 200 acre landfill according to an approved engineering plan. A proposal by facility operators to utilize the ash residue as a final cover material (to support vegetation) on this abandoned landfill is currently being evaluated by the Department.

Testing programs instituted in the past seven years have attempted to assess leaching properties of the residue, and have included laboratory lysimeter and elutriate studies utilizing tap water, distilled water, acidic solutions and ambient acid precipitation (eastern Massachusetts). In-situ testing programs at the RESCO site and controlled residue deposition areas in Waltham and North Andover, Massachusetts, are also under review.

While stressing the on-going status of many of the residue studies, the following is a compendium of information, conclusions, and speculations on this material, as currently understood by the Department:

(1) GENERAL CHARACTERISTICS - The generic term "ash residue" has been taken to mean those end products of high temperature refuse combustion consisting of a heterogeneous mixture of "bottom" ash (riddlings, clinkers) and "fly" ash (furnace fly ash, electrostatic precipitator fly ash). At the RESCO facility in Saugus, the bottom and fly ash waste streams are combined, directed to a quench channel drag conveyor, and ultimately removed from the plant as a combined ash residue mixture.

In the context of the end-of-process mixture defined above, the RESCO residue is a combination of inert ash, unburned organic and inorganic material, some ferrous metal, and glass slag. The residue is angular, free draining, alkaline, and purported to be biologically sterile. The total volatile solids content of the residue has been reported to be in the area of 2.4% by weight or less, indicative of a relatively complete refuse incineration process.

(2) CHEMICAL COMPOSITION - Significant differences in contaminant concentrations have been reported by various researchers, undoubtedly due to the residue's intrinsic variability, different sampling methodologies, analytical procedures and perhaps significantly, bottom/fly ash ratios.

In general terms, the RESCO residue contains elevated levels of mineral salts and alkalinity, and high concentrations of some heavy metals including lead, cadmium, copper, and zinc.

(3) RESIDUE LEACHABILITY - High concentrations of mineral salts and heavy metals in the RESCO residue is not in itself a cause for concern. Rather, the real and potential leaching properties of the residue material willultimately determine its environmental compatibility and scope of utilization.

Inorganic leaching isa complex phenomenon, dependent upon such factors as the types and distribution of compounds, the pH and ionic strength of the solute, the types and concentrations of complexing ligands, and the redox environment of the leaching system. Interfacing laboratory and "real world" conditions is difficult, especially when trying to evaluate long-term potentials. Nevertheless, the leaching of soluble salts and certain heavy metals from the RESCO residue has appeared with some frequency, yielding a preliminary indication of overall leachate patterns.

Clearly, substantial leaching of readily soluble salts from "fresh" ash residue has been well documented, at least in terms of specific conductance measurements, which can average 2500 μmhos/cm^2 or more upon initial leachate generation. Ions leached from these salts include sodium, iron, calcium, potassium, magnesium, phosphorous, chlorides, nitrates, and sulfates. The leaching of heavy metals from the ash residue, though proportionately minute, are of key environmental concern.

Ash testing programs to date have not disclosed massive leaching of heavy metals from the mixed residue, even when subjected to prolonged exposure to ambient "acid precipitation" (pH=4.0) conditions. Data from several testing programs and methodologies, however, appear to implicate lead and cadmium as heavy metals with significant short and long term leaching potential. In some instances, lead and cadmium concentrations have exceeded allowable limits in the EPA EP Toxicity procedure, although this test is probably more of a regulatory classification procedure than an absolute measurement of leachability.

Lead is a ubiquitous contaminant emanating from a variety of common waste sources. High levels of lead contained within the RESCO residue, however, may be attributable to lead-base inks utilized for newsprint. (It is interesting to note that paper and cardboard products comprise 40 to 50% of "typical" municipal refuse; newspapers and magazines alone comprise an estimated 15%.)

It is speculated that the high concentrations of cadmium contained in the RESCO residue is due to the presence of plastic products in municipal solid wastes, as cadmium is utilized as a stabilizer and pigment in common consumer thermoplastics, including polyolefins, polyvinyl chloride, and polystryene. The percentage of thermoplastics in municipal refuse is expected to increase substantially in the future from a present value around 5%, to 13 to 20% by the year 2000.

(4) BUFFERING ABILITY OF RESIDUE - Field and laboratory studies on RESCO ash residue undertaken at the University of Massachusetts Waltham Experiment Station since 1977 have identified a persistent ash buffering capacity in that residue samples exposed to ambient acid precipitation events (mean pH=4.0) will produce a leachate with a mean pH value of 7.9. This alkaline buffering characteristic has important implications to residue leachability, since, in general, trace metal species are least soluble under alkaline conditions. However, although this neutralization mechanism is not totally understood, it is presumably of a finite nature, which creates speculation as to the long-term stability of the residue and the potential for a future breakdown of the material due to physical, chemical, and/or biological processes.

(5) BOTTOM/FLY-ASH COMPOSITION - As previously mentioned, the end-of-process waste product exiting the RESCO plant is a mixture of "bottom" ash and "fly" ash, with the bottom ash component comprising the bulk of the mixture. Newer facilities of this type, however, often segregate these two component wastestreams.

Recent test data has disclosed that bottom and fly ash components may have substantially different properties; future testing programs will attempt to further define these discrepancies.

(6) RESCO PLANT PROCESSES - The physical and chemical characteristics of incinerator ash residue are a direct function of (1) the nature of the raw refuse, (2) incinerator design, and (3) incinerator operational parameters. Thus significant differences in residue properties can exist between individual incineration facilities. (this is especially true in consideration of the substantial differences between European and American refuse).

The major effect of high temperature refuse incineration is the almost total exchange of inorganic salts for organic compounds, the partial oxidation of metals, and the physical concentration and intermingling of metallic compounds and inorganic salts.

Operational parameters at the RESCO plant in Saugus, to the extent they may impact on residue generation and chemical properties, have recently been analyzed in great detail by the facility operators, the results of which are currently under review by the Department.

(7) CONTINUING RESEARCH PROGRAMS - The analyses of a material as heterogeneous as the RESCO reside is necessarily data-intensive. Existing and future research programs will attempt to further define short and long term chemical characteristics and will address such topics as bottom/fly ash differentiation, residue structure and chemical speciation, dissolution characteristics and kinetics, buffering mechanism (quantification), soluble salt leaching, and EP Toxicity testing.

In conclusion, while some of the residue's physical properties have been evaluated, many questions still remain relative to the nature and stability of this material. In addition to being a severe impediment to product sampling and laboratory analyses, the heterogeneous nature of the ash residue makes data analysis difficult and complicates environmental assessment.

The Department is presently compiling and analyzing existing data on the RESCO residue. The technical data will be utilized to identify environmentally appropriate ash disposition options, and the Department will formulate a regulatory position on the handling, use and disposal of the RESCO residue consistent with applicable laws and regulations.

Additional research or data may be necessary for the Department to make such a determination. The next step in this process will be a Departmental review of the existing data to identify information gaps. If the current data is insufficient, the Department will collaborate with parties conducting research on the RESCO residue during the generation of the requiste information.

The Department of Environmental Quality Engineering is a proponent of resource recovery facilities such as RESCO. Given the sometimes unsanitary and polluting nature of conventional "sanitary" landfills, energy and metal recovery facilities are viewed as an environmentally attractive method of solid waste management, if for no other reason than to physically reduce waste volumes requiring land disposal. Of course, facility ash residues must be managed properly.

Nationally, RESCO has been at the forefront of resource recovery technology and implementation, and as such has encountered and dealt with many situations unique to the field. The evaluation and characterization of the facility's residue is yet another area lacking precedent that will require original research and study. Once sufficient information has been derived, proper residue management and disposal procedures can be engineered.

The Department of Environmental Quality Engineering is the state's environment regulatory agency responsible for developing, administering, and enforcing programs which regulate air, surface water and groundwater, water supplies, wetlands, and solid and hazardous waste.

APPENDIX 10.13

DESIGN CALCULATIONS FOR THE RESIDUE/UNPROCESSABLE WASTE LANDFILL

Introduction

The following design calculations consider the surface water management plan for the project during its final phase. During this phase Cells 1 and 2 will be completely filled and stormwater storage will be provided in a stormwater pond and the diked FPL easement.

Peak design elevations will be highest during this project development phase and thus the 10-year - 24 hour, 25 year - 72 hour and 100 year - 72 hour design storms have been applied to this phase.

During the initial phase of development (i.e., landfilling of Cell 1) the area set aside for Landfill Cell 2 will also be utilized for stormwater storage. Design calculations for this phase for the 25 year - 72 hour design storm are included in this Appendix.

I. Final Phase - Cells 1 and 2 capped.

A. Water Quality Design Criteria

SFWMD water quality guidelines for retention storage require a retention volume equal to 50% of the runoff from the 3 yr. - 1 hr. storm (precipitation = 2.8 inches).

Impervious Drainage Area = 131.2 acres
Swale Area = 18.6 acres

Determine weighted runoff coefficient

Runoff coefficient (impervious areas) = 0.9
Runoff coefficient (pervious areas) = 0.2

$$\text{Weighted runoff coefficient} = \frac{(0.9) \times (131.2) + 0.2 \times (18.6)}{149.8} = 0.81$$

Retention storage required

= 0.5 x (0.81) x (2.8 inches) x (1 ft/12 inches) x (149.8 acres)
= 14.2 ac/ft

For a control elevation of +2.0 feet NGVD, determine minimum discharge elevation to retain 14.2 ac-ft of stormwater in the stormwater pond and FPL easement.

TABLE 1

TOTAL STORAGE - SWALE, FPL EASEMENT AND POND

El (ft)	Swale (Ac-ft)	FPL Eas (Ac-ft)	Pond (Ac-ft)	Total (Ac-ft)
2	0	0	0	0
3	0	6.7	1.5	8.2
4	0	14.1	3.0	17.1
5	0	22.1	4.5	26.6
6	10.7	32.0	6.0	48.7
7	23.2	42.3	7.5	73.0
8	37.4	52.9	9.0	99.3
9	53.3	63.8	10.5	127.6
10	71.2	75.0	12.0	158.2

Interpolating between total storage achieved for elevations of 3 and 4 feet, the outfall weir must be set at El. +3.7' NGVD for 14.2 Ac-ft retention in stormwater pond and FP&L easement.

B. Peak Discharge Criteria

A stormwater runoff model (DRAINCALC) which is based on SCS TR-55[1] (24 hour type II storm event) was utilized to

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[1] Calculations based on methodology presented in "Urban Hydrology for Small Watersheds: Technical Release No. 55; Soil Conservation Service January, 1975.

determine the pre-development discharge hydrograph. Conservatively, the first two days of rainfall were ignored. The following information was input into the model:

Drainage Area = 149.8 acres
Precipitation = 11.0 inches, (34d day of design storm)
*Time of Concentration = 95 minutes
**Curve Number = 78

*Based on Soil Conservation Services (SCS) velocity method of determining the time of concentration. Flow length - 2400 ft. with an average overland flow velocity of 0.42 ft/sec.

**Natural ground elevations are 0 to 2.0± ft. with soil condition D. Reported curve number assumes a meadow in good condition (see U.S. Department of Agriculture, SCS Technical Release No. 55, "Urgan Hydrology for Small Watersheds" - 1975).

The predevelopment peak design discharge as calculated in the model is 434.3 cfs. Using SCS TR-55 tables and assuming 25% ponding throughout the watershed the peak runoff adjustment factor for a 25 year storm = 0.57.

Assuming a watershed slope of 0.1%, the slope adjustment factor for the site = 0.32.

Thus, the adjusted peak discharge for the site is:

$$(0.57) \times (0.42) \times (434.3) = 104 \text{ cfs}$$

Results: Limit post development peak design discharges below 104 cfs.

Utilizing the same methodology, i.e. the DRAINCALC model hydrographs and SCS TR-55 tables, the post-development peak runoff rate is 2551 cfs.

Using SCS TR-55 the following can be attained:

Given:

Limiting Discharge: Q_o = 104 cfs

Runoff Peak Rate: Q_i = 2551 cfs

Runoff Volume (conservatively): V_r = 15 in.

Result

The storage volume required to attenuate post-development runoff discharges to 104 cfs is 125.5 acre feet.

With this storage volume, calculate the storage elevation with weir set at elevation +4.0 NGVD:

From Table 1:

El. (ft)	Total Retention Vol. (Ac-ft)
8	99.3
8.9*	125.5
9	127.6

*Interpolation between 8 and 9 feet of available storage volume.

Summary

High water elevation in the capped configuration is approximately +8.9 feet NGVD with discharge weir set at elevation +4.0 feet and +8.6 feet NGVD with weir set at elevation +3.7 feet. Say retention pond high water level will be at elevation +8.6 feet NGVD since weir at elevation +3.7 feet is adequate for water quality retention and discharge control with tailwater elevation assumed at +3.0 feet NGVD in C-11 Canal.

II. Initial Development Phase - Cell 1 Operational

In this case Cell 2 will be utilized for stormwater retention purposes during the landfilling of Cell 1. This will be achieved by hydraulically connecting Cell 2 to the stormwater retention basin.

As stated earlier, for the 25 year - 72 hour design storm the limiting discharge is 104 cfs and the runoff peak rate is 2551 cfs.

From SCS TR-55 tables, the required storage volume to limit post-development stormwater discharges to predevelopment levels is 125.5 Ac-ft.

With the outfall weir set at elevation +4.0 feet NGVD calculate the storage/elevation assuming no swale storage in Cell 2, control elevation in Cell 2 is +2.0 feet NGVD, and FP&L easement will not be used during initial Cell 1 development (only retention pond utilized).

Utilizing DRAINCALC model the following was computed:

Elevation (ft)	Vol. Cell 2 (acre-feet)	Vol. Retention Pond (acre-feet)	Total Storage (acre-feet)
2	0	0	0
3	50.5	1.5	52.0
4	101.0	3.0	104.0
4.4*			125.5
5	151.5	4.5	156.0

*Interpolation between elevation 4 and 5 feet of available storage.

Calculate preliminary length of outfall weir:

- With weir set at elevation +4.0 feet NGVD, and a discharge flow rate of 104 cfs for the design storm. With 0.4 feet of surcharge head on the weir (4.4'-4.0'), the approximate length of weir, (sharp crested) required is 128'.
- With weir set at elevation +3.7 feet NGVD, the approximate length of weir required is 55'.
- If the water elevation is allowed to pond to elevation +5.9' NGVD weir length required is approximately 10 feet.

Therefore set the outfall weir at elevation +3.7 NGVD, provide approximately 10 feet of weir length and allow water to pond in Cell 2 and retention pond to elevation +5.9 feet NGVD.

DESIGN CALCULATIONS FOR THE RESOURCE RECOVERY FACILITY

I. Design Criteria

a) Water Quality: Retain 50% of 3 year - 1 hour storm (precipitation = 2.,8 inches)

b) Peak Discharge: Limit discharge to 24 year - 72 hour storm (precipitation = 15.0")

c) Utilize two retention ponds with areas equal to 3.4 acres and 4.3 acres for total of 7.7 acres.

d) Control elevation equals +2.0 feet NGVD.

e) High water elevation is approximately +5.3 feet NGVD for 25 year storm with outfall weir elevation of +3.0 feet NGVD.

f) Peak discharge of 90.7 cfs to C-11 Canal.

II. Site Land Use

Total Drainage area = 38 acres

Where:

	Acres	% of Total
Impervious (buildings, roads, parking)	8	21.1
Pervious	30	78.9
Landscaped	(22.3)	
Retention/Detention	(7.7)	
	38	100.0

III. Provide Water Quality Criteria

A. Retain 50% of 3 year - 1 hour storm (2.8")

Note: Calculations based on methodology presented in Urban Hydrogology for Small Watersheds: Technical Release No. 55; Soil Conservation Service, January 1975, which uses of 24 hour, Type II storm distribution.

1. Develop Runoff Curve Number for developed site:

Use	Curve No.		Area (ACS)		Composite
a. Bldgs, roads, parking lots, etc.	98	x	8	=	784
b. Landscaped, ponds, etc.	80	x	30	=	2,400
			38		3,184

(Note: CN = 74, based on open space with good grass cover placed on relatively permeable structural fills, i.e., crushed limestone, etc.; high groundwater.

Weighted runoff curve number = $\frac{3,184}{38}$ = 84

2. From Table 2-1 (interpolated for CN-84 and 2.8 in.) Runoff depth from 2.8 inches = 1.36 inches.

B. Vol. retained in basins at 50% of 3 year - 1 hour storm

$$0.50 \times 38 \text{ acres} \times 1.36 \text{ in.} \times \frac{1'}{12''} = 2.15 \text{ acre-feet}$$

C. Depth of storage in ponds at discharge of 3 year - 1 hour storm.

$$D = \frac{2.15 \text{ acre ft}}{7.7 \text{ acres}} = 0.279' = 3.3'' \text{ for } 50\% \text{ retention}$$

Set control elevation of weir to discharge 3 year storm at 3.3" surcharge above lowest selected control elevation.

IV. Peak Discharge

A. 25 year - 72 hour storm (15"); 38 acres (Note calculations based on TR-55)

1. Runoff curve number prior to development:

CN = 89 (Table 2-2, Pasture, poor condition poorly drained)

2. Runoff prior to development:

From EQS 2-5, 2-7 (TR-55)

Runoff depth from 15 inches = Q = 13.61 inches (unadjusted)

Peak discharge from Figure D-2 (flat slope) (TR-55) for 38 acres, CN-89, peak discharge = 26 cfs/in. of runoff. Since site is very flat with little grade, peak flows must be adjusted. Adjustment for flat slopes of <1% is taken from Table E-1 (TR-55). For slope of 0.1% (characteristic of site), adjustment factor - 0.45 (for slope). Furthermore, swampy and ponding areas will attenuate peak flows further. Therefore, an additional correction is applied from Table E-3 (TR-55). Assuming that approximately 25% of site area is swampy, for 25 year storm the frequency adjustment factor = 0.57 (for ponding).

Therefore peak discharge from predevelopment site = 13.61 in. x 26 cfs/in. x (0.45) x (0.57) = 90.7 cfs for 25 year - 72 hour storm.

Limit peak discharge to 90.7 cfs after development.

Detention Basins

Compute developed site discharge for 25 year storm runoff depth from 15 inches: CN = 84: Q = 12.94 inches

From Figure D-2 (flat slopes) for CN = 84, DA = 38 acres peak discharge = 23 cfs/in. of runoff. Adjust for ponding - 0.57. Therefore, peak discharge for developed site:

12.94 in. 23 cfs/in x (0.57) = 169.6 cfs for 25 year - 72 hour storm

Determine required storage to attenuate discharge to 90.7 cfs.

Q_o (desired outflow) = 90.7 cfs

Q_i (future condition inflow) = 169.6 cfs

$$\frac{Q_o}{Q_i} = \frac{90.7}{169.6} = 0.534$$

Determine V_s (storage volume) from Figure 7-2 (TR-55)

For:

$$\frac{Q_o}{Q_i} = 0.534 \quad \frac{V_s}{V_r} - 0.262$$

For:

V_r = 12.94 in. V_s = (0.262) x 12.94 in. = 3.39 in.

$$\text{Storage} = \frac{(3.39 \text{ in}) \times (38 \text{ acres})}{12 \text{ in/ft.}} = 10.74 \text{ ac-ft.}$$

With 7.7 acres for basins, then the minimum surcharge height at discharge:

$$\frac{10.74 \text{ ac-ft}}{7.7 \text{ acres}} = 1.39'$$

Say 1.4' for outflow structure with 90.7 cfs capacity.

Preliminary Basin Design

The site control elevation is +2.0 NGVD. Weir elevation to be set at elevation +2.3' to provide sufficient storage for 50% of the 3 year - 1 hour storm for quality control. To attenuate peak flows from the 25 year - 72 hour storm so as not to exceed predevelopment discharge a minimum of 10.74 acre-feet of storage is required. Assume that this storage will be provided above elevation 2.3' (weir crest). Also discharge from the basins must not exceed 90.7 cfs. Basins should be provided with a minimum freeboard of 0.5 feet in addition to depth above crest. Outflow control structure would contain a weir to control discharge to C-11 Canal. Table 2 below presents preliminary analysis of 7.7 acre basin and outlet control structure to meet design criteria.

TABLE 2

PRELIMINARY ANALYSIS - BASIN/OUTFLOW STRUCTURAL

Storage Provided	Storage Requires	Depth Above Crest Elevation	Surcharge Elevation at Discharge	Length of Weir for Limiting Discharge
10.47 acre=feet	10.47 acre-feet	1.4 ft.	+3.7 ft. NGVD	17'
19.25 acre-feet	10.47 acre-feet	2.5 ft.	+4.8 ft. NGVD	7'
23.10 acre-feet	10.47 acre-feet	3.0 ft.	+5.3 ft. NGVD	5'

Summary: Pond storage elevation of 5.3 feet NGVD is maximum estimated elevation for site, and the estimated length of the weir to limit discharge is five feet.

Appendix 10.14

BROWARD COUNTY, FLORIDA
SYNTHETIC LANDFILL LINERS

Introduction

This report describes the results of a study on the state-of-the-art application of flexible membrane liners used for the containment of landfilled materials including municipal solid waste, ash residue from power generation units (coal) and industrial waste. The objectives of the study were to assemble information concerning the chemical and physical properties and field performance of various synthetic liner materials. Specifically, the categories of investigation are as follows:

- The effect of MSW leachate and industrial waste sludges on the physical and chemical properties of various synthetic liner materials. This category includes testing in accordance with ASTM standards of liner materials after exposure during laboratory and field conditions.
- Design standards which minimize the adverse effect of differential settlement on synthetic liner materials.
- The effect of a landfill fire on synthetic liner materials.

Information was sought concerning the following commercially available flexible membrane liners and fabric-reinforced flexible membrane liners as they occur in the following four types of polymers:

1. Vulcanized Elastomers:

    Butyl rubber
    Chlorinated polyethylene (CPE)
    Chlorosulfonated polyethylene (CSPE, Hypalon)
    Ethylene propylene rubber (EPDM)

2. Thermoplastic Elastomers (TPE):

    Chlorinated polyethylene (CPE)
    Chlorosulfonated polyethylene (CSPE, Hypalon)

3. Thermoplastics:

   Plasticized polyvinyl chloride (PVC)
   PVC with selected elastomers

4. Crystalline polymers (thermoplastic):

   High Density Polyethylene

Information used in this report was obtained from literature searches, manufacturers, fabricators, suppliers, and installers of liners; and interviews and discussions with various consultants, industry personnel, and testing laboratories.

Summary of General Liner Properties (from USEPA Publication, "Lining of Waste Impoundment and Disposal Facilities").

a. Polyvinyl Chloride

PVC liners are produced in roll form in various widths and thicknesses. Most liners are used as unsupported sheeting, but fabric reinforcement has been used. PVC compounds contain 25% to 35% of one or more plasticizers to make the sheeting flexible and rubber-like. They also contain 1% to 5% of a chemical stabilizer and various amounts of other additives. The PVC compound should not contain any water soluble ingredients. A wide choice of plasticizers can be used in PVC sheeting, depending upon the application and service conditions under which the PVC compound is to be used. Plasticizer loss during service is a source of PVC liner deterioration. There are three basic mechanisms for plasticizer loss: volatization, extraction, and microbiological attack. The use of the proper plasticizers and an effective biocide can virtually eliminate microbiological attack and minimize volatility and extraction. The PVC polymer, itself, is not affected by these conditions. It is affected, however, by ultraviolet exposure.

The principal reason for loss of plasticizer is by volatization in the heat of the sun rather than solution in the waste fluid. Carbon black prevents ultraviolet attack but does cause the absorption of solar energy raising the temperature to a high level to cause vaporization of the plasticizer. A soil or other suitable cover material used to bury the liner protects it from ultraviolet exposure and reduces the rate of plasticizer loss. PVC sheeting is not recommended for exposure to weathering and ultraviolet light conditions during its service life. In some burial tests and in some liner applications, PVC sheetings have become stiff, presumably due to loss of plasticizers. Some plasticizers can be degraded by microorganisms, while others can be extracted, to a limited extent, by water.

Plasticized PVC sheeting has good tensile, elongation, puncture and abrasion resistance properties. It is readily seamed by solvent welding, adhesives, and heat and dielectric methods.

PVC membranes are the most widely used of all polymeric membranes for waste impoundments. They show good chemical resistance to many inorganic chemicals; however, they are attached by many organic chemicals, particularly hydrocarbons, solvents, and oils which extract the plasticizer. Special compounds of PVC are available, designated as Oil-Resistant PVC (PVC-OR), that possess high resistance to oil attack. These "oil-resistant" grades of sheeting must be made with "specialty" plasticizers; the PVC polymer is inherently resistant to the effects of oils.

b. Chlorosulforated Polyethylene (CSPE, Hypalon)

Hypalon, produced by Dupont, is characterized by ozone resistance, light stability, heat resistance, good weatherability, and resistance to deterioration by corrosive chemicals, e.g. acid and alkalies. It has good resistance to growth of mold, mildew, fungus, and bacteria. Membranes of this material are available in both vulcanized and thermoplastic forms, but primarily in the latter. Usually, they are reinforced with a polyester or nylon scrim and generally contain at least 45% of CSPE polymer. The fabric reinforcement provide the necessary tear strength for use on slopes, and reduces the distortion resulting from shrinkage when placed on the base and when exposed to the heat of the sun. The latter is more suitable for lining industrial and hazardous waste impoundments.

CSPE can be seamed by heat sealing, dielectric heat sealing, solvent welding, or by using "bodied" solvent adhesive. Membranes of this polymer do not crack or fail at extreme temperatures or from weathering. Disadvantages of unreinforced CSPE membranes are low tensile strength and a tendency to shrink on exposure to sunlight due to the heat absorbed. Also, thermoplastic CSPE tends to harden on aging, due to crosslinking by moisture, ultraviolet radiation, and heat and has relatively poor resistance to oils. The hardening can cause problems in repairing damaged sheetings due to crosslinking of CSPE, which can make it insoluble and difficult to heat seal.

c. Polyethylene

One type of polyethylene, high density polyethylene (HDPE), has been used as a landfill liner material since the mid-1970's. It is available in sheetings of 20-120 mils in thickness, is an unreinforced product, and is free of additives such as plasticizers and fillers. HDPE is characterized by its high resistance to oils, solvents, permeation by water vapor and gases, and weathering; as well as, its high tensile strength, puncture resistance, and excellent elastic properties. Seaming of HDPE liner material is performed in the factory and in the field by an extrusion welding process which if properly performed yields a seam which is stronger than the parent material. Because HDPE is stiffer than most liner materials and because fusion seaming is more involved than solvent seaming, HDPE liners take somewhat longer to install.

Physical and Chemical Compatibility of Liner Materials

The information contained herein was obtained from the USEPA publication entitled "Lining of Waste Impoundment and Disposal Facilities", and from manufacturers and suppliers of synthetic liner materials.

Because of the potential impact that pollutants from waste disposal sites might have on the groundwater quality, EPA initiated research work in this area to determine the state-of-the-art with respect to liners and to assess the various liners available under conditions which simulated as closely as possible actual service conditions. EPA felt that the test results from this type of evaluation would give the greatest credibility to the use of lining materials for land waste disposal facilities.

a. Laboratory Results of Exposure to MSW Leachate

The primary liners were recovered from landfill simulators after 12 and 56 months of exposure.

The results of the analyses and physical testing of the specimens before and after exposure are presented in Table 1. These test results are divided into analyses, physical properties, and seam strength and are arranged by liner material and exposure time. The following is a summary of Table 1:

- CSPE, CPE and EPDM materials absorbed the most leachate.
- EPDM and PVC lost about 10% of its plasticizer.
- In general tensile strength increased (Figure 1).
- Puncture strength did not change appreciably.
- There was a significant drop in several cases in seam strength; however, this loss in adhesion did not results in any seepage.

Overall, the changes in the physical properties of the membranes resulting from 56 months exposure to MSW leachate was relatively minor. None of the liners showed any seepage. The absence of seepage confirms the very low permeability of the membrane lining materials and the adequacy of the seams that were placed in the liners.

b. Exposure of Membrane Liners to Hazardous Waste

The EPA study was concerned with the laboratory evaluation of various commercial lining materials upon exposure to a variety of hazardous wastes under conditions which simulate real service.

The wastes included two strong acid wastes, a strong alkali waste, an oil refinery tank bottom waste, a lead waste from gasoline, saturated and unsaturated hyrocarbon wastes, and a pesticide waste. Results show the variation in the volatiles and extractables both with respect to the polymer type and the waste. There are indications that, in some cases, the plasticizer which was in the original compound was removed during the exposure period. In other cases, the extractables were higher, indicating the absorption of nonvolatile constituents in the waste.)

The effects of 3.5 years of exposure to the waste varies considerably with the liner material and the waste. Only one material, a polyester elastomer, completely lost its elongation and that was in exposure to a strongly acidic waste. The CSPE, and EPDM liners lost significant elongation in the caustic, lead, and nitric acid wastes, respectively. The CSPE and PVC liners stiffened during exposure to the wastes and the neoprene liner softened. The CSPE crosslinked during exposure and the PVC probably lost plasticizer.

Table 2 provides a summary of the compatibles of various liner materials with various industrial hazardous wastes.

c. Test Results

Test results provided by liner manufacturers and supplier's regarding the compatibility of synthetic liner materials with a large number of chemicals is provided in the following tables:

Table 3 - Oil Resistant CPE
Table 4 - Polyvinyl Chloride
Table 5 - Hypalon
Table 6 - HDPE

In selecting polymer and rubber compounds for service in a liquid medium, a designer generally selects materials which have low or negligible swell. Swelling of a compound can have adverse effects which will make the product unserviceable. Some of the major effects of swelling generally are:

- Softening
- Loss or tensile and mechanical strength
- Loss of elongation
- Increased permeability
- Increased potential of creep
- Greater susceptibility to polymer degradation

All of these effects are adverse with respect to liner performance. Swelling, therefore, is a valuable indicator of the compatibility of a liner to a waste.

Shrinkage can also be a measure of compatibility for liner compositions that are highly plasticized. For example, in the case of highly plasticized PVC compounds, the plasticizer can leach and diffuse out of the polymer leaving the compound stiff and brittle.

Therefore, in Tables 3, 4, and 5 one should look for a small weight change in order to determine liner chemical compatibility. Table 6 provides outright chemical compatibility of various types of liner materials.

In sum, more often than not, for a given chemical environment, there are several types of synthetic membrane liner materials which exhibit chemical compatibility. It should be noted that the leachate from a MSW or ash residue landfills would generally be less aggressive than many of the hazardous and industrial waste listed in the above tables; therefore, liner performance with respect to chemical comptability can be expected to be good.

Settlement Capability

There are several potential modes of liner failure due to physical processes, one of which is differential settlement. Differential settlement can damage all liners. This problem is best mitigated with a thorough geologic analysis prior to site selection and careful subgrade design and construction. Differential settlement is a localized stress phenomenon and the greater the thickness and elasticity of the liner, the greater the tolerance range for differential settlement. Therefore, the inherent elasticity of some synthetic liners, serves to mitigate settlement effects by conforming to the subgrade if movement occurs.

Upon review of the literature and information provided by manufacturers and suppliers, the most acceptable liner material for the mitigation of differential settlement on the market today is HDPE. Its attributes include:

(For HDPE between 60 and 100 mils in thickness)

a. Elongation
   15% at yield
   800% at break

b. Tensile strength
   2,500 psi at yield
   3,500 psi at break

c. 100% weld strength (fusion weld)

d. highly puncture resistant

e. highly chemical resistant

Its drawbacks include:

a. somewhat greater difficulty in installation - HDPE is stiffer than most liner materials, and fusion seaming is more time and quality control intensive than solvent seaming.

Further mitigation of a differential settlement problem can be achieved by installing a double liner using a material such as PVC which has a fairly high elasticity (300% at break). The purpose of utilizing two liners, separated by several feet of sand, is to distribute the stresses induced by localized settlement by distributing the load over a wider area. Likewise, the use of geotextiles in lieu of or with sand fill will function to strengthen the liner system and distribute stress.

HDPE liner material has successfully been utilized to mitigate differential settlement. A municipal sanitary landfill located in southeastern Pennsylvania was built over a depository of discarded cars. The design incorporated two layers of HDPE material 30 and 40 mils in thickness. The combination of sheets and 100% integrity seam welding provided the flexibility and security required to compensate for the possibilities of upward movement and downward settlement. Hazardous waste disposal sites in New York State using HDPE liner have been designed to accommodate expected settlement.

Proper foundation design can help reduce the amount of differential settlement. The installation of a drainage system under the liner can prevent hydrostatic pressures from building up. These pressures change the stresses on the foundation soil (sand) and may make it more susceptible to differential settlement by causing a shift in the soil.

The Effect of Landfill Fires on Synthetic Liners

The result of discussions with personnel from liner manufacturers and suppliers as well as engineering consultants involved with synthetic liners, is that landfill fires should have a negligible effect on synthetic liner materials. This conclusion is based on the following factors:

a. The liner will be covered with one to two feet of sand. This sand cover will act as an effective insulator by virtue of its low thermal conductivity. There is a large percentage of voids in a medium grained sand; therefore, the entrapped dead air and water (if saturated) will act as an insulator.

b. The "flash point" or ignition temperature where many liner materials will burn if in contact with flame is in the neighborhood of 350°F for PVC and 675° for HDPE. The effect on these liners when they reach these temperatures is to melt and disintegrate. The important point here is that flame must come in contact with the liner material; if one utilizes a soil cover this cannot happen.

c. The highly chlorinated liner materials such as PVC and Hypalon will burn if in contact with flame but will not support flame by virtue of the high chlorine content of the material. Chlorine gas smothers the flame.

d. After discussions with many industry personnel only one sanitary landfill, lined with a synthetic liner, was reported to have had a fire. The liner was 4 to 5 feet below the fire and was unaffected.

Existing Lined Landfills

Table 7 identifies landfills that have successfully utilized synthetic liner materials to protect underlying groundwater. Tables 8 and 9 provide supplemental lists of landfill liner installations as provided by installation companies.

Conclusions

Based on the information gathered during the course of this study, the following conclusions have been formulated:

a. Available literature contains sufficient engineering and laboratory performance data on which to base an engineering analysis of synthetically lined land impoundment sites for various forms of municipal and industrial wastes.

b. The method of utilizing flexible membrane liners to prevent groundwater contamination by leachate from waste impoundment facilities is a highly developed technology. With proper design cosiderations, these liners will be physically and chemically compatible with a given landfill environment. Proper quality control during construction and facility operation are the most important variables in successful liner performance.

TABLE 7

LANDFILLS UTILIZING SYNTHETIC LINER MATERIALS

Landfill Location	Year in Operation	Type of Waste	Material Utilized	Comments
Cathcart LF in Snohomish, WA	1981	MSW	35 and Hypalon 36 mil PVC	Staff Inc. installation
Crawford County, OH demonstration LF (EPA Study)	1971	MSW	30 mil PVC	Liner tested after 6 yrs. of exposure; buried material should little change in overall properties incl. seam strength
Boone County, KY, LF and EPA Field Site	1972	MSW	CSPE, CPE, LDPE	LF was operated by EPA Solid and Hazardous Waste Research Division. All materials showed little overall change in physical properties.
EPA Field Site	Operational for 6.5 yrs.	Industrial Sludge	15 mil PVC	Conclusions drawn: PVC should be covered and should be thicker than 15 mils.
Experimental LFs at Georgia Institute of Technology (EPA Study)		MSW	CSPE (unreinforced)	After 4 years in operation, only minor changes in physical properties of the material was encountered.
Brookhaven Landfill in N.Y.		MSW	PVC	Facility was expanded by adding 2nd layer of PVC.
New Jersey L.F.	1980	MSW	Hypalon	All physicals after 18 months burial were normal with tensile modulus increasing. See Table 10 for specific test data.
New Hampshire Superfund Project		Hazardous Waste	40 mil HDPE	Gundle installation.
Southeastern Pennsylvania		MSW	Double liner 30 and 40 mil HDPE	1st landfill installed under the Pennsylvania Title 25 regulations. Differential settlement expected.

TABLE 7

LANDFILLS UTILIZING SYNTHETIC LINER MATERIALS
(continued)

Landfill Location	Year in Operation	Type of Waste	Material Utilized	Comments
Kansas		Hazardous Waste	60 mil HDPE	Site upgrade, install liner over clay. The installation is monitored by a leak detection system
New Hanover County, N.C.	1980	MSW	Double Liner 36 mil Reinf. Hypalon 20 mil PVC	1st synthetically lined sanitary LF in N.C.
Cecos Site in Cincinnati, OH	1974	Hazardous Waste	HDPE	Superfund project - this site accepts hazardous waste from many parts of the country. Has a leak detection system.
Tampa, Florida		Flyash and Ash Residue	HDPE	Stone and Webster project; 2.5 million square feet of liner.
Cecos Site Niagara Falls	1981	Hazardous Waste	HDPE	Active permitted hazardous waste disposal site
SCA Site Pinewood S.C.	1984	Hazardous Waste	HDPE	Active permitted hazardous waste disposal site
SCA Site Model City, N.Y.	1982	Hazardous Waste	HDPE & Hypalon	Active permitted hazardous waste disposal site
Town of No. Hempstead, N.Y. Landfill	1983	MSW	PVC-OR	Next section will contain PVC-OR bottom liner and HDPE top liner with leak detection system
Croton Point Landfill Westchester Co. N.Y.	1983	MSW	PVC	Active permitted hazardous waste disposal site

c. The selection of a liner material for a waste impoundment site should involve the following considerations:

- The liner material should satisfactorily resist attack from all chemicals (solvents, oils, greases, etc.), ozone, ultraviolet radiation, soil bacteria, mold, fungus, and vegetation to which it will be exposed. Resistance can be determined by laboratory testing of the liner material in the waste that the liner will contain.
- The liner material should have ample strength and weather resistance to withstand the stresses associated with wetting and drying, freezing and thawing, subgrade conditions and settlement dictated by the geographic location and geologic setting of the impoundment site.
- The liner material should have adequate physical properties to withstand the stresses of installation from machinery or equipment.
- The liner material should be resistant to laceration, abrasion, and puncture during operations from any matter that may be found in the materials that it will contain. Landfill operation should be planned to protect the liner system.
- The liner material should be easily reparable at any time during its life (particularly when repairs are feasible), and it should be the most economical material that can adequately fill the specific application.
- The liner material should be properly installed. Improper installation of even the best material will defeat the purpose of the lining.
- To provide longer life and protection against mechanical damage and weathering, all flexible membrane liner materials, both exposable and unexposable, should be covered with a layer of sand or fine-textured soil.
- Drainage systems should be installed both above and below the liner in order to prevent fluid pressure builduip which can cause settlement or unnecessary pressure.

- Proper filling and maintenance of the liner and impoundment site should be practiced.

d. In addition, the EPA recognizes the use of synthetic liner materials as being the most acceptable method to prevent contamination of the groundwater at hazardous waste disposal sites. The following excerpts have been taken from the Federal Register dated July 6, 1982, the subject being "EPA Design Performance Requirements for Hazardous Waste Impoundments, Piles and Landfills."

  - "... in the cases of landfills and of surface impoundments used to dispose of hazardous waste, the regulations provide that the liner must be constructed of materials that prevent wastes from passing into the liner. Synthetic liners are the only commonly used materials of which EPA is aware that would meet this standard."

  - "When a synthetic membrane liner... is installed in a landfill, the leachate collection and removal system installed above the liner (as required by today's regulations for landfills and piles) can achieve virtually a 100% removal efficiency. In contrast, if a clay liner is used, some leachate will seep into the liner rather than be removed through the drainage layer."

REFERENCES AND CORRESPONDENCES

1. USEPA Publications:

    a. Lining of Waste Impoundment and Disposal Facilities. EPA-530/SW-870, Revised March 1983.

    b. Liner Materials Exposed to Municipal Solid Waste Leachate. EPA-600/2-79-038. July 1979.

    c. State-of-the-Art Study of Land Impoundment Techniques. EPA-600/2-78-196. December 1978.

    d. Liner Materials Exposed to Hazardous and Toxic Sludges. EPA-600/20-77-081. June 1977.

2. Information provided in writing and during telephone interviews by the following synthetic Liner Manufacturers, Fabricators and Suppliers:

    Schlegel Lining Technology, Inc.
    Gundle Lining Systems, Inc.
    Watersaver Company, Inc.
    Staff Industries
    B.F. Goodrich Company, Engineered Rubber Products Division

3. Information provided during telephone interviews with the following consulting firms and private testing laboratories.

    E.A. Engineering
    Matrecon, Inc.
    National Sanitation Foundation

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Appendix 10.15

State of Florida
DEPARTMENT OF ENVIRONMENTAL REGULATION

INTEROFFICE MEMORANDUM

For Routing To District Offices
And/Or To Other Than The Addressee

To: [illegible] Loctn.:
To: Loctn.:
To: Loctn.:
From: [illegible] Date:

Reply Optional [ ] Reply Required [ ] Info. Only [ ]
Date Due: Date Due:

RECEIVED
APR [illegible] 1983
DIVISION OF ENVIRONMENTAL PERMITTING

TO: Steve Fox SF

FROM: Hamilton S. Oven, Jr. HSO

DATE: April 19, 1983

SUBJECT: Use of Fly Ash

I have reviewed the material assembled by Bill Hennessey and Jim Estler concerning the use of flyash. Additionally, I have reviewed material supplied by Monier Resources, Inc. and an EPA guideline published in the January 28, 1983 Federal Register. It is my conclusion that the use of flyash mixed with lime or cement will have no significant adverse environmental impacts when used as a road or parking lot subbase or road base material.

I have also been studying the use of a flyash, lime or cement and flue gas desulfurization sludge mixture as a potential low strength soil cement material. This material sets up like a low strength concrete. It is a relatively impermeable (5×10^{-6} cm/sec - 5×10^{-8} cm/sec) material. The heavy metal species in the flyash are usually chemically bound during the cementing process.

In both the lime-flyash and lime-flyash-FGD sludge mixtures, the flyash becomes cemented together with alumino-silicates which reduces the surface area available for leaching. The low permeability of the resulting material also reduces the leaching potential.

It is my recommendation that the department allow use of flyash in construction products subject to the precautions outlined by Jim Estler's memo of 12/17/82 as follows:

Flyash may be used as a construction material when mixed with lime or cement, water, and aggregate in proper proportions to form a stable concrete like material with the following safeguards:

1. Transportation of flyash from generator to a temporary storage site or batch plant must be accomplished in a dust free manner either by tank trucks or covered dump trucks with enough water to ensure dust free transport.

2. Generators should store flyash in an acceptable manner either in a dry state in an enclosed system with emissions controlled by approved dust collectors or in an approved landfill site with precautions taken to ensure no groundwater or surface water contamination. The landfill site should be provided with an irrigation system to control fugitive dust during storage and material handling.

3. Temporary storage site must be in conformance with No. 2 above.

4. Preparation of the flyash mixture must be accomplished at a permitted batch plant. Flyash should be stored in a silo equipped with a dust collector. Material transfer points, mixer, and any other potential source of particulate emissions should be adequately controlled. Open stock piling of flyash at the batch plant or construction site should be prohibited.

5. Flyash shall not be used as a fill or embankment material.

6. Flyash must be used in conjunction with lime or cement (not limestone unless mixed with lime or cement) and water to form a pozzolanic product.

7. Placement must be above the high groundwater table and should be underdrained if necessary.

8. Mixture must be covered by an impervious surface coat.

In regards to the request of Mr. E. Edward Holloway, Jr. to use a flyash material to consolidate phosphate slimes, I have several comments. The department might consider a test program to allow such grouting under certain conditions. Such conditions might include:

1. A showing by the applicant that sufficient clay beds surround the site to preclude contamination of aquifers. The clay beds should be continuous at least two to five feet thick with a permeability not to exceed 1 x 10^{-7} cm/sec.

2. A pilot test should be done in which the clay slimes, flyash, lime and FGD sludge are mixed and allowed to cure for 28 days. After curing, the resulting mixture should be tested for leachability, compression strength, permeability, etc.

3. If the results of 1 and 2 above are satisfactory and indicate no potential leachate problems, then the grouting could be allowed under controlled conditions including monitoring of groundwater quality.

cc: Bill Hennessey

State of Florida
DEPARTMENT OF ENVIRONMENTAL REGULATION

INTEROFFICE MEMORANDUM

For Routing To District Offices
And/Or To Other Than The Addressee

To: ______ Loctn.: ______
To: ______ Loctn.: ______
To: ______ Loctn.: ______
From: ______ Date: ______
Reply Optional [ ] Reply Required [ ] Info. Only [ ]
Date Due: ______ Date Due: ______

TO: W. K. Hennessey

THROUGH: Dan Williams
Bill Thomas
Harry Kerns

FROM: Jim Estler

DATE: December 17, 1982

SUBJECT: Fly Ash

Pursuant to your request, a literature review was conducted on materials received from Monier Resources, Inc. and Power Plant Siting. The following is a brief review of my findings and recommendations:

I. Background Information:

Fly ash along with bottom ash and boiler slag are generated by the combustion of coal. Approximately 75-85% of the ash generated is fly ash. The chemical, physical and engineering properties of fly ash are influenced by many factors including: type and variability of coal composition; degree of coal pulverization; type of furnace; firing temperature and other operating parameters; characteristics of ash collection and disposal properties; environmental effect (eg: leaching, weathering, self-hardening, etc.); and time.

Fly ash is composed of fine particles that are predominately spherical in shape, solid or hollow, and of a glass or amorphous nature.

The chemical properties of fly ash vary from source to source. However, in general the primary constituents are silica, alumnia, and iron oxide with lesser amounts of calcium, magnesium, sulfur and unburned carbon. Trace elements typically present are arsenic, boron, cadmium, chromium, copper, lead, selenium and zinc. The later are of little importance with respect to the use of fly ash for construction type applications; however, they are of a concern in an environmental sense. If these elements could be leached out of fly ash material in quantities which exceed environmental standards, then problems could be created for the commerical use of fly ash.

Fly ash is of interest in the construction industry because of its pozzolanic properties. A pozzolan is defined as a siliceous or aluminous and siliceous material which is in itself chemically inert, and possesses little or no cementitious value, but, when in a finely divided form and in the presence of water, will react with calcium hydroxide at ordinary temperatures to form compounds possessing cementitious properties. Properties similar to the reaction products of Portland Cement.

Attachment I summaries the coal fired utilities in the area and fly ash disposal/use practices.

II. Fly Ash Stabilization of Subgrade and Base Roadway Material:

The issue at hand is whether the District should allow, based on potential environmental problems, the use of fly ash as a subgrade and base material in roadway construction.

The representatives from Monier Resources, Inc. have related the following information to Harry Kerns:

1. Fly ash would be mixed with cement or lime, water, possibly some type of aggregate. Use would be restricted to road base and subbase material.

2. Mixing would be accomplished at a batch plant with the necessary controls taken to prevent air and water pollution. Fly ash would be stored in a silo and fugitive dust problems would [illegible] minimized.

3. Any temporary storage of fly ash material would be at an approved landfill site (i.e.: Parsons Pit).

To date, none of the literature reviewed has specifically addressed the environmental issues relating to the use of fly ash as a roadbase material. Buck Oven has expressed a concern over the general use of fly ash. The material he sent to the District pertained to the water quality issues related to wet and dry ash storage and stockpiling. We are aware of the potential leachate problem and it has been specificaly addressed in Parson's Pit design. However, the disposal practices (either temporary or long term) of coal fired utilities in our area should be investigated to insure no degregation of groundwater and/or surface water quality.

Reports reviewed cover the use of fly ash (sometimes including bottom ash and coal slag) mixed with lime, limestone, and/or cement to form a cementitious compound. High performance base course applications are composed of mixtures with lime, cement or limerock (with cement or lime added).

In an EPA draft final report on "Data Collection and Analyses Pertinent to EPA's Development of Guidelines for Procurement of Highway Construction Products Containing Recovered Materials," [illegible] a section on fly ash used in structural fills the statement is made that "compacted fly ash has low permeability, particularly if it is self-hardening, and indications thus far are that the material does not leach potentially hazardous concentrations of inorganic chemicals". This section also recommends that "the placement of fly ash in a fill or embankment must be accomplished above the anticipated high water table and the material must be underlain by a drainage blanket or opengraded granular material".

The EPA report referenced above made some very general statements about the uses of LFA (Lime-Fly Ash-Aggregate) mixtures. In regards to air pollution it states that some is generated and is a result of "aggregate mining and crushing, and that the handling of fly ash results in more particulate pollution than the asphalt option". "The dust problem created by material handling may cuase some adverse impact in terms of air quality".

With regard to water pollution "No significant water pollution is generated directly by the LFA system, but some water pollution is generated by the production of fuels used in various steps".

EPA published the "Guideline for Federal Procurement of Cement and Concrete Containing Fly Ash" in the November 20, 1980 Federal Register (40 CFR 249). This document recommends the use of fly ash in cement and concrete material used in Federal projects and requires it to be included in the bid specifications.

The Federal Highway Administration is also promoting the fuller utilization of waste products (ie: fly ash), particularly where there is a potential for energy conservation. They are trying to convence the State DOT to develop this philosophy. The USDOT has published two volumes entitled: "Soil Stabilization in Pavement Structures A Users Manual" (FHWA-IP-80-2) dated October 1979, which includes a section on lime-fly ash stabilization.

Various states around the country use and have specifications to use fly ash in roadway construction activities. My understanding is the Floirda DOT is reviewing the use of fly ash at this time and that they are somewhat hesitant to give an agency O.K.

III. Recommendations:

The following proposal addresses the environmental issues associated with the use of fly ash as a base and subgrade material in roadway construciten (These recommendations do not reflect an endorsement nor has an evaluation been made in regard to its structural properties.)

A. Fly ash mixed with lime or cement, water, and aggregate does not pose an adverse environmental hazard if safeguard measures are undertaken.

B. Safeguards are:

1. Transportation of fly ash from generator to a temporary storage site or batch plant must be accomplished in a dust

free manner. Either by tank trucks or covered dump truck with enough water added to ensure dust free transport.

2. Generators store fly ash in an exceptable manner. Either in a dry state in an enclosed system with emissions controlled by approved dust collectors or in an approved landfill site with precautions taken to ensure no groundwater or surface water contamination. The landfill site should be provided with an irrigation system to control fugitive dust during storage and material handling.

3. Temporary storage site must be in comformance with No. 2 above.

4. Preparation of the fly ash mixture be accomplished at a permitted batch plant. Fly ash to be stored in a silo equipped with a dust collector. Material transfer points, mixer, and any other potential source of particulate emissions should be adequately controlled. Open stock piling of fly ash at the batch plant or construction site should be prohibited.

5. Fly ash shall not be used as a fill or embankment material.

6. Fly ash must be used in conjunction with lime or ceme (not limestone unless mixed with lime or cement) and water tc form a pozzolanic product.

7. Placement must be above the high groundwater table and should be underdrained if necessary.

8. Mixture must be covered by an impervious surface coat.

C. Rational:

1. Water: Based on the information reviewed regarding the cementitious properties of fly ash when combined with cement or lime and water it appears reasonable to assume that the resultant compound would not be prone to leaching. Further, limiting its contact with groundwater and providing a impervious surface layer to prevent contact with precipitation, afords us with additional assurances of preventing leachate problems.

2. Air: Adequate controls of fly ash during storage, transfer, and transport will control fugitive dust problems.

D. Comments From Tallahassee:

Buck Oven's group has been reviewing a request from the Electric Power Research Institute about the potential us c fly ash. He advised me in our 12-16-82 telephone conversatic that its use as a fill or embankment material (ie: unstabilized) could create potential problems. However, in stablized form as a pozzolanic compound and with additional safeguards (ie: impervious top coat and above the high groundwater table) he saw no potential environmental problem with its use.

IV. General Comments on Fly Ash:

A. Monier Resources, Inc. has questioned whether DER would permi the dumping of FPL's fly ash from oil fired plants at Parsons's Pit.

1. Bill Deane advised me on 11-10-82 that since the source o fly ash (Crystal River) was specified in the landfill application (and not in the permit), the Department would require the permittee to request a formal modification of the permit to allow the site to be used to store fly ash from other sources. This would open the door to third party intervention.

2. The literature reviewed did not contain any information on fly ash generated from oil fired power plants. Therefore, it would be advisible to request ash analysis from several plants along with leachate tests.

B. Fly Ash Used as a Agricultural Soil Conditioner:

No information has been received regarding this issue and until such time as it is and has been reviewed by DER and he Department of Agriculture, its use should not be allowed. This is due to the potential negative environmental effect on groundwater quality. Plant take up may render some crops unfit for human consumption, and Cu and Zn may be absorbed in sufficent concentrations to be toxic to plants.

JE/scm

NOTES ON FLY ASH HANDLING - COAL FIRED POWER PLANTS

TECO (phone conversation with John Ramil on 10-27-82)
All coal fired plants (Big Bend 1&2 and Gannon 5&6) pneumatically convey the fly ash from the ESP to a storage silo(s).

Some units share a common silo. Emissions are controlled by baghouses.

They sell all their fly ash to a broker (Mineral Aggregates) which sells it to Florida Mining and Materials which uses it in the manufacturing of cement.

Fly ash is transported by an enclosed truck(tanker).
TECO produces 219,000 tons/year of fly ash.

City of Lakeland McIntosh Unit #3 (Phone conversation with Bill Rodrigues on 10-27-82)

Fly ash from the ESP is conveyed to a storage silo via a pneumatic system. Emissions are controlled by a series of baghouses. They are temporarily stock piling the ash in the landfill area. They use water sprays and a Nalco product to control emissions. Ultimately, they will mix the fly ash, bottom ash, scrubber sludge, and concentrate from the cooling tower to form a slurry which solidifies in 24-hours. This concrete like substance called Pozotech can be used as a road base material. Currently, have an agreement from Polk County to use the material. They are looking for someone to actually buy and use the substance. The system is designed to produce 83,516 tons of fly ash/year.

Florida Power conversation with Dennis Shantz on 10-21-82

Bartow No. 1 - Fly ash handling is part of the construction permit for the ESP, at least on baghouse involved. It is handled dry, using a solids pump from the ESP to a storage silo. Water spray is used at the end of the conveyor system from the silo as it is transferred to the stock pile in the landfill area. They have a fire hose at the landfill area to control fugitives should a problem develop.

They intend to sell the fly ash when they can locate a buyer.

Crystal River - Units 1 & 2 pneumatically convey fly ash to a series of storage silos. Fly ash is either transported dry in a tanker truck or wet in an open body truck to landfill site.

BEST AVAILABLE COPY

SIGNAL RESCO, Inc
10 UOP Plaza
Des Plaines, Illinois 60016
312-391-2341
A Subsidiary of UOP Inc.

November 28, 1983

Mr. Ray Moreau
Environmental Supervisor, Resource Recovery Program
State of Florida Dept. of Environmental Regulation
Twin Tower Office Building
2600 Blair Stone Road
Tallahassee, FL 32301-8241

Subject: DER Questionnaire

Dear Mr. Moreau:

Your letter of October 13, 1983 to Mr. D. F. Acenbrack, Pinellas County Department of Solid Waste Management, was forwarded to me for response.

The information that you requested is contained on the attached eight pages.

I would appreciate receiving a copy of questionnaire results from other resource recovery facilities from around the country that are made available to your office.

I trust that the information we have supplied is adequate but if there is need for clarification please contact me directly at 312/391-3744.

Very truly yours,

Andrew M. Szurgot

mb

Attachment

C: D. F. Acenbrack (w/att.)
L. K. Batton (w/att.)

Subject: Pinellas County Project
DER Questionnaire Concerning
Ash Characteristics

A copy of the subject questionnaire is attached for reference. The answers to the questions follow.

1. Ash Analyses

The material discharged from the grate, referred to as bottom ash in the questionnaire, is combined with the fly ash collected from the various boiler and precipitator hoppers. The combined residue goes to a materials recovery system where metals are removed. The recovered metals comprise from 10% to 20% of the total mass of combined residue on a dry basis depending on the composition of the incoming municipal solid waste (refuse). The material remaining after the metals are recovered, referred to as aggregate, is sent to landfill for disposal. Table I identifies the elemental analysis of the combined hopper and flyash, and aggregate.

2. EP Toxicity Test Results

The EP Toxicity testing was conducted under the auspices of the County. A copy of the test report is attached.

3. Operating Parameters

a. Temperatures and Residence Times

The design temperature profile across the unit and the residence time at design conditions in each zone are shown in Table II for the case when firing municipal solid waste (refuse) having a higher heating value (HHV) of 5000 Btu/lb at a rate of 1000 TPD.

b. Air Requirements

Each unit operates at excess air rates in the range of 60% to 95%.

c. Burnout Efficiency

The percentage of inorganic carbon in the combined residue is guaranteed not to exceed 5.0% by weight (dry basis) when firing refuse with a higher heating value (HHV) of 4500 Btu/lb.

4. Other Information

a. Air Pollution Control Equipment

Each unit is equipped with an Air Correction Division, UOP Inc. electrostatic precipitator of the weighted-wire type. Each precipitator consists of 3 active/1 empty mechanical (6 active/1 empty electrical) fields. The outlet grain loading from each ESP is guaranteed not to exceed 0.08 gr/dscf corrected to 12% CO_2.

b. Ash Quench System

Burned out material from the grate is quenched in a water bath. Then it is allowed to drain in order to remove excess moisture. The collected fly ash is conditioned with water for dust control before adding it to the quenched material discharged from the grate. There is no water effluent from the ash quench and conditioning system.

c. Mixing Ratio of Fly Ash to Grate Ash

All of the collected fly ash is combined with all of the material discharged from the grate. Although the exact amount of fly ash will depend upon the characteristics of the refuse being fired, the fly ash will comprise approximately 11% by weight of the total combined residue.

d. Ultimate Disposal of the Combined Residue

The material discharged from the grate is combined with the fly ash collected in the various boiler and precipitator hoppers. The combined residue goes to a materials recovery system where metals are removed. The aggregate remaining is sent to landfill for disposal. The recovered metals are sold.

DER Questionnaire

1. Dry-weight analyses for combined fly and bottom ash. Same for each ash separately.

2. Any E.P. Toxicity test results.

3. Facility operating parameters, including:

   - temperature ranges
   - residence time
   - air requirements
   - burnout efficiency

4. Other information:

   - air pollution control train employed
   - ash quench systems utilized (and any reagents added and analyses available on the effluent)
   - mixing ratios of flyash to bottom ash
   - the form of residue ultimate disposal or reuse

NOTE: If any of the above information has already been generated in existing reports, you are welcome to send me copies of the reports instead of answering the questions directly in separate correspondence.

Table I

Elemental Analysis of Hopper Ash and Aggregate

Element	Concentration Unit	Concentration	
		Hopper Ash(1)	Aggregate
Cadmium	ppm	< 10.3	< 10
Magnesium	"	13,700	4,630
Zinc	"	10,640	1,330
Silicon	"	128,000	397,000
Copper	"	665	1,930
Nickel	"	156	39
Manganese	"	1,815	629
Calcium	"	109,700	62,900
Molybdenum	"	172	25
Cobalt	"	48.0	22
Aluminum	"	53,500	18,000
Titanium	"	14,600	3,690
Vanadium	"	87.9	26
Chromium	"	936	185
Iron	"	11,100	23,700
Lead	"	3,640	450
Barium	"	1,530	482
Beryllium	"	NR	11
Mercury	"	28.6	0.96

NOTES:

(1) Combined ash collected from the economizer and precipitator hoppers.

(2) NR = Not Reported.

(3) The results for each material represent the average of two grab samples.

EP Toxicity Test Report

ESE

ENVIRONMENTAL SCIENCE
ND ENGINEERING, INC.

June 21, 1983

ESE No. 83 405 400

Mr. William Dasher
Director Public Works Operations
Pinellas County Solid Waste Department
2800 110th Avenue North
St. Petersburg, FL 33702

Dear Mr. Dasher:

Enclosed are the results of the two waste samples collected on 5/27/83 and the two residue samples collected on 6/6/83 at the Pinellas County Refuse to Energy Facility. The samples can be described as follows:

ESE Sample No.	Sample Description	Sample Date
246902	Waste (5/26/83)	5/27/83
246903	Waste (5/27/83)	5/27/83
46904	Aggregate Residue	6/06/83
246906	Non Separated Residue	6/06/83

The maximum allowable concentrations are also provided on the data reports. Results from all four samples are below the maximum allowable concentrations.

Sample numbers 246904 and 246906 yielded a positive reaction to acid and a negative reaction to base when subjected to the reactivity test. The results indicate that the positive reaction is due to carbonates in the samples and hence the samples should not be considered hazardous for the reactivity criteria.

A third sample (#246905) of the non-ferous residue was also collected on 6/6/83. This sample consisted of non-magnetic residue from two to ten inches in size. The nature of this sample made it impossible to sieve it to the required size as specified in the EP Toxicity Test. The DER recommended that this sample was not suitable for the test and hence no analysis was conducted.

Please call me if you have any questions.

Sincerely,

Karen Hatfield

Karen Hatfield
Project Manager

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JUN 27 1983
U.O.P./S.W.S.D.

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JUN 23 1983
PINELLAS COUNTY
SOLID WASTE SYSTEM

KLH:ceg
Enclosures

RESULTS OF ANALYSES

SAMPLES COLLECTED AT THE PINELLAS COUNTY REFUSE TO ENERGY FACILITY 5/27/83

ESE Sample No. Sample Description	246902 Dumped 5/27	246903 Dumped 5/26	Max. Conc. Allowed
Arsenic, Diss (ug/L)	<22	<22	5000
Barium, Diss (ug/L)	363	252	100000
Cadmium, Diss (ug/L)	4.2	4.9	1000
Chromium, Diss (ug/L)	170	160	5000
Lead, Diss (ug/L)	<30.0	<30.0	5000
Mercury, Diss (ug/L)	<12	<12	200
Selenium, Diss (ug/L)	<39	<39	1000
Silver, Diss (ug/L)	<4.0	<4.0	5000
Zinc, Diss (ug/L)	5.9	1.9	500000
Endrin, Diss (ug/L)	<0.010	<0.010	20
Lindane, Diss (ug/L)	<0.002	<0.002	400
Methoxychlor, Diss (ug/L)	<0.1	<0.1	10000
Toxaphene, Diss (ug/L)	<0.5	<0.5	500
2,4-D, Diss (ug/L)	<10	<10	10000
2,4,5-TP, Diss (ug/L)	<10	<10	1000
Gross Beta, Diss (ug/L)	112	150	100000
Radium 266, Diss (ug/L)	1.5	0.4	300
pH (Corrosivity)	12.2	12.0	2->12.5
Ignitability	>212°F	>212°F	>212°F
Reactivity	Neg	Neg	Neg

Karen Hatfield

Karen Hatfield, Project Manager

RESULTS OF ANALYSES

CERTIFICATION SAMPLES COLLECTED AT THE PINELLAS COUNTY REFUSE TO ENERGY FACILITY 6/6/83

ESE Sample No. Sample Description	246904 Aggregate	246906 Non Separated	Max. Conc. Allowed
Arsenic, Diss (ug/L)	<22	<22	5000
Barium, Diss (ug/L)	295	312	100000
Cadmium, Diss (ug/L)	169	494	1000
Chromium, Diss (ug/L)	8.2	91	5000
Lead, Diss (ug/L)	991	2110	5000
Mercury, Diss (ug/L)	<12	<12	200
Selenium, Diss (ug/L)	<39	<39	1000
Silver, Diss (ug/L)	<4.0	<4.0	5000
Zinc, Diss (ug/L)	6830	16600	500000
Endrin, Diss (ug/L)	<0.010	<0.010	20
Lindane, Diss (ug/L)	<0.002	<0.002	400
Methoxychlor, Diss (ug/L)	<0.1	<0.1	10000
2,4-D, Diss (ug/L)	<10	<10	10000
2,4,5-TP, Diss (ug/L)	<10	<10	1000
Gross Beta, Diss (ug/L)	132	426	100000
Radium 226, Diss (ug/L)	0.7	0.7	300
pH (Corrosivity)	12.2	10.6	2->12.5
Ignitability	>212°F	>212°F	>212°F
Reactivity	Neg/Pos*	Neg/Pos*	Neg
Toxaphene, Diss (ug/L)	<0.5	<0.5	500

* See explanation in attached letter

Karen Hatfield

Karen Hatfield, Project Manager

Table II

Temperature Profile and Residence Times

Refuse HHV: 5000 Btu/lb
Firing Rate: 1000 TPD

Location	Parameter	Units	Value
Combustion Chamber	Flue gas temperature above grate	°F	~2010
	Flue gas temperature at flame end	°F	1747
	Flue gas temperature at outlet	°F	1539
	Total residence time combustion chamber	Sec.	4.1
Boiler	Flue gas temperature at boiler outlet	°F	450
	Total residence time in boiler	Sec.	10.6

STATE OF FLORIDA
DEPARTMENT OF ENVIRONMENTAL REGULATION

TWIN TOWERS OFFICE BUILDING
2600 BLAIR STONE ROAD
TALLAHASSEE, FLORIDA 32301-8241

BOB GRAHAM
GOVERNOR

VICTORIA J. TSCHINKEL
SECRETARY

MEMORANDUM

TO: District and Subdistrict Managers

THROUGH: Steve Fox
Howard Rhodes
Greg Parker GLP
Bob McVety
John Reese

FROM: Ray Moreau

DATE: December 19, 1983

SUBJECT: Agency Position on the Use of Fly Ash Material, Including Aggregate from Resource Recovery Facilities.

There have been several inquiries from the districts concerning the above subject. In response, I have attached a package of information on fly ash for your use, review, and comment. This package includes the January 28, 1983 Federal Register, copies of memos on fly ash use from Buck Oven and Jim Estler, and copies of ash laboratory analyses from the Pinellas County Refuse-to Energy Facility.

The Solid Waste Section is revising Chapter 17-7, FAC, and the revisions will include specific regulations and guidelines on fly ash disposal and use (these revisions will be prepared for ERC adoption in April 1984). In the interim, this agency's position on the use of fly ash should be to follow the guidelines outlined in Buck Oven's memo which is attached. Disposal of fly ash material should be in a lined landfill.

If you have any questions or comments concerning this memo or the enclosures, please don't hesitate to contact John Reese or me at Suncom 277-1128.

RM/pe

Enclosures

cc: Marshall Mott-Smith
Jim Estler
Rodney DeHan
Buck Oven

ENVIRONMENTAL PROTECTION AGENCY

40 CFR Part 249

[SWH-FRL 2176-8]

Guideline for Federal Procurement of Cement and Concrete Containing Fly Ash

AGENCY: Environmental Protection Agency.

ACTION: Final guideline.

SUMMARY: The Environmental Protection Agency (EPA) is today issuing final guidelines for the Federal procurement of cement and concrete containing fly ash, implementing Section 6002(e) of the Resource Conservation and Recovery Act of 1976, as amended (RCRA). Section 6002 of RCRA requires procuring agencies using appropriated Federal funds to purchase items composed of the highest percentage of recovered materials practicable. Section 6002(e) instructs EPA to prepare guidelines to assist procuring agencies in complying with the requirements of Section 6002.

This guideline designates cement and concrete containing fly ash as a product area for which affirmative procurement actions are required, in accordance with Section 6002. Fly ash is a component of coal resulting from its combustion, and is the finely divided mineral residue which is typically collected from boiler stack gases. The guideline provides recommendations to procuring agencies which are expected to stimulate greater recovery and reuse of fly ash.

The preamble to the guideline explains EPA's regulatory strategy for fulfilling its responsibilities under Section 6002 of RCRA.

DATE: Effective February 28, 1983.

ADDRESS: Single copies of the final guideline, and RCRA, are available from:

RCRA Hotline (800) 424-9346 (In the Washington, D.C. area call 382-3000)

Public Docket: The public docket for this guideline is located in: Room S289C, U.S. Environmental Protection Agency, 401 M Street, SW., Washington, D.C. 20460, and is available for viewing 9:00 a.m. to 4:00 p.m. Monday–Friday excluding holidays.

FOR FURTHER INFORMATION CONTACT: John Heffelfinger, Hazardous and Industrial Waste Division, Office of Solid Waste (WH-565), U.S. Environmental Protection Agency, 401 M Street, SW., Washington, D.C. 20460; (202) 382-4761.

SUPPLEMENTARY INFORMATION: Proposal and Comments: The proposed guideline was published on pages 76906–76921 of the **Federal Register** of November 20, 1980, and invited comments from the public on its contents until January 15, 1981. At the request of some commenters the comment period was reopened until January 30, 1981. Notice of reopening of the comment period was published on pages 9132–9133 of the **Federal Register** of January 28, 1981. A total of 161 written comments were received on the proposed guideline, including 12 late comments. This is in addition to oral comments received at the public hearing held on January 8, 1981 at EPA Waterside Mall, where approximately 75 persons attended and 21 presented formal testimony. The public docket for this guideline is available for viewing as mentioned above.

Introduction

Purpose and Scope

The Environmental Protection Agency is today promulgating the first of a series of guidelines designed to encourage the use of products containing recovered materials. Section 6002 of the Solid Waste Disposal Act, as amended by the Resource Conservation and Recovery Act of 1976, as amended ("RCRA" or "Act"), 42 U.S.C. 6962, requires Federal, State, and local procuring agencies using appropriated Federal funds to purchase items composed of the highest percentage of recovered materials practicable. EPA is required to prepare guidelines to assist procuring agencies in complying with the requirements of Section 6002.

This preamble also explains EPA's regulatory strategy for fulfilling its responsibilities under Section 6002 of RCRA.

RCRA

The objectives of the Resource Conservation and Recovery Act are the protection of human health and the environment and conservation of valuable material and energy resources. The Act sets forth a national program to achieve these objectives by improving solid waste management practices. The provisions of the Act include: (1) Requirements for control of the generation, transportation, treatment, storage, and disposal of hazardous wastes, (2) establishment of environmentally sound disposal practices for all wastes, and (3) investigation and creation of incentives for resource recovery and conservation activities. These activities are to be carried out through a cooperative effort among Federal, State, and local governments, as well as private industry.

Requirements of Section 6002

Section 6002 of the Act, titled Federal Procurement, directs all procuring agencies which use appropriated Federal funds to procure items containing the highest percentage of recovered materials practicable, given that reasonable levels of competition, cost, availability, and technical performance are maintained. This requirement applies only to those products which are designated by guidelines issued by EPA under Section 6002(e). Further, only items where the purchase price of the item exceeds $10,000, or where the quantity of such items purchased during the preceding year exceeded $10,000, are subject to these purchasing requirements.

Federal procuring agencies responsible for drafting or reviewing specifications are required to review and revise specifications for products in order to eliminate any discrimination against the use of recovered materials. They are to remove specifications requiring that items be manufactured from virgin materials, and remove prohibitions against the use of recovered materials.

Vendors are required to estimate the percentage of recovered materials utilized for the performance of the contract and to certify that it is at least the amount called for by the specifications or other contractual requirements.

Section 6002 gives the Environmental Protection Agency responsibility for promulgating guidelines to assist procuring agencies in carrying out these requirements. The EPA guidelines are to designate those products which can be produced with recovered materials and whose procurement by procuring agencies will fulfill RCRA objectives. EPA guidelines are to provide specific recommendations with respect to the procurement of products containing recovered materials. In conjunction with the Office of Federal Procurement Policy in the Executive Office of the President, EPA has responsibility for implementing the policy and program at all levels of government.

Section 6002 is aimed at achieving the materials conservation goal. Its clear objective is to use the economic incentive of Federal procurement to increase the recovery of solid waste materials. Federal procurement of products made from recycled materials can demonstrate their technical and economic viability as they are used by Federal, State and local agencies.

Guideline for Federal Procurement of Cement and Concrete Containing Fly Ash

Purpose

The purpose of this guideline is to increase the use of cement and concrete containing fly ash which is purchased with Federal funds. Fly ash is a by-product of coal combustion. Its increased use in cement and concrete will help reduce this source of solid waste. At the same time this will conserve both significant amounts of energy and natural resources used in making cement. Cost savings can be achieved while providing a product that can be equivalent or even superior to cement and concrete made using only virgin materials.

This guideline will increase the demand for recovered fly ash in federally-funded construction. This increased demand should improve the marketability of fly ash and promote wider acceptance of it as a cement substitute and concrete additive. This together with the cost savings of fly ash in local markets may result in its more widespread use in non-federally funded construction as well.

Contents of the Guideline

This guideline designates cement and concrete, including concrete products such as pipe and block, containing fly ash as a product area for which procuring agencies must exercise affirmative procurement under Section 6002 of RCRA and presents recommendations for carrying out the requirements of Section 6002 with respect to fly ash used in cement and concrete. RCRA defines procuring agencies to include not only Federal agencies, but also State and local agencies, grantees, and contractors which are using Federal funds to purchase cement and concrete.

Section 6002 of the Act sets forth certain requirements for procuring agencies. These requirements include: (1) Eliminating from specifications any discrimination against the use of recovered materials; (2) purchasing products which contain recovered material if reasonable levels of technical performance, cost, availability, and competition can be achieved; and (3) obtaining certification from suppliers that they have met any minimum contractual requirements for including recovered materials.

To assist procuring agencies in achieving compliance with these requirements, this guideline recommends that procuring agencies which purchase cement or concrete adopt a procurement approach which specifically allows that fly ash can be used as an optional or alternate material in the performance of the contract, either in a blended cement or as an admixture in concrete. This recommendation applies except in those cases where the use of fly ash would be technically inappropriate.

Flexibility is allowed procuring agencies in meeting this recomendation. For example, some agenices may prefer to allow for fly ash use through changes in contract specifications, with the option to use fly ash left to the discretion of the successful offeror. In other cases, agencies may prefer an alternate bid approach, and solicit bids for portland cement or concrete alone, and for portland cement or concrete containing fly ash.

In addition, this guideline recommends that procuring agencies revise their guide specifications and design guidelines to ensure that fly ash use is allowed, except where technically inappropriate. It suggests certification procedures which utilize the existing review and approval mechanisms already imposed by procuring agencies.

Phased-in implementation, with specification changes to be made in the first year after publication of this guideline and purchases to begin in the second year, is recommended.

Explanation of Current Regulatory Approach

General vs. Specific Guidelines

Soon after EPA undertook the effort to prepare procurement guidelines, it became clear that guidelines could not be developed for all 50,000 Federal product specifications and standards. EPA did not have the resources to review all 50,000 Federal product specifications and make decisions on what percentage of recoverable materials is technically and economically feasible, available in a reasonable amount of time, and produced by enough companies to guarantee that competition is maintained.

The Solid Waste Disposal Act Amendments of 1980 (Pub. L. 96-482) require a product-specific approach in issuing guidelines. These amendments key all of the purchasing requirements of Section 6002(c) to the preparation by EPA of guidelines for particular products and direct EPA to "designate those items which are or can be produced with recovered materials and whose procurement by procuring agencies will carry out the objectives of (Section 6002)."

Statute Requirements vs. Guidelines

A few commenters on the proposed guideline expressed confusion over the relationship between the requirements of Section 6002 and the recommendations of the guidelines. They asked for clarification of whether the recommendations contained in the guidelines must be adhered to.

EPA is of the opinion that the guidelines are, in general, voluntary. They contain recommendations for achieving compliance with the mandatory provisions of the statute, i.e., Section 6002. The mandatory provisions of the statute for a particular product area are triggered, for the most part, by EPA's designation of that product under Section 6002(e).

Although the guidelines contain recommendations rather than requirements, EPA is of the opinion that compliance with the guidelines constitutes compliance with the statute. However, there may be alternative methods of complying with the statute, not specifically addressed by the guidelines. As long as compliance with the intent of Section 6002 can be established, these alternative methods should be considered acceptable.

Criteria for Selection of Product Areas

In the proposed guideline, EPA proposed criteria to aid in the selection of product areas for which guidelines will be prepared. These criteria were:

(1) The waste material must constitute a significant solid waste management problem due either to volume, degree of hazard or difficulties in disposal;

(2) Economic methods of separation and recovery must exist;

(3) The material must have technically proven uses; and

(4) Federal purchasing power for the final product must be substantial.

In the main, these criteria incorporate all of the factors which the Solid Waste Disposal Act Amendments require EPA to consider in selecting products for the issuance of guidelines.

Some commenters suggested adding to or revising these criteria. One commenter suggested a criterion that the recycled product must not displace a currently recycled product, for example, home scrap as reused within a steel mill. EPA agrees in principle that by designating a product for affirmative procurement actions, a currently recycled product should not be precluded from use. By taking the product-specific approach which is required by Section 6002, sufficient investigations would be performed to assure that this does not occur. We should add, however, that the definition of "recovered material" contained in RCRA "* * * does not include those materials and by-products generated from, and commonly reused within, an original manufacturing process." Thus, home scrap would not qualify as a recovered material for purposes of Section 6002.

Other commenters suggested that energy conservation be included as a criterion for product selection. EPA believes that while use of waste materials may indeed conserve energy, the overriding thrust of Section 6002 must be the impact on solid waste. Thus, it would be inappropriate to reject products from consideration which could result in a significant impact on the solid waste stream, but for which a slight increase in energy consumption would result. Likewise, if significant energy reductions could be achieved while having little or no impact on the solid waste stream, it would be inappropriate for EPA to issue procurement guidelines under Section 6002.

One commenter suggested revising the criterion of Federal purchasing power from being "substantial," to "a great deal." In considering this comment as well as suggestions for additional product areas for the issuance of guidelines, it became apparent that the criterion should focus on the extent to which the Federal government can affect use of waste materials through the procurement guideline mechanism. In some cases, changes resulting from direct purchasing with Federal funding may not be as significant as changes which may take place at State and local levels, and in the private sector, due to the "ripple effect" which changes in Federal procurement practices may have. Therefore, the fourth criterion has been revised to read as follows:

> (4) The Federal government's ability to affect purchasing or use of the final product or recovered material must be substantial.

One commenter suggested inclusion of a criterion for uses which may be expected to develop in the future. EPA rejected this suggestion because it is in opposition to the fundamental concept that the guidelines can only designate products which are technically and economically proven, and available in a reasonable period of time from enough persons to assure that competition is maintained. Other governmental programs may be aimed at demonstrating, for example, the technical feasibility of using a waste material in lieu of a virgin material in a pilot-scale project. Such use may be further developed in the future. However, the mechanism of Federal procurement guidelines is inappropriate for such product development efforts. For the guidelines to be effective, products must have been fully developed and somewhat available, but suffering from resistance to their use. Experimental or developmental products do not fall into this category.

Product Areas Currently Under Study

With these criteria in mind, EPA has chosen four major product categories for the issuance of guidelines under Section 6002. These categories are cement and concrete containing fly ash, recycled paper products, spent pickle liquor from steel finishing processes as used in wastewater treatment operations, and highway construction products containing recovered materials, particularly lime-fly ash-aggregate road base and subbase mixtures. The issuance of a guideline for composted sewage sludge, as mentioned in the proposed guideline, has been deferred, due to higher priority commitments within EPA at the present time. EPA expects additional candidate products to surface through its industry solid waste studies program. As guidelines are completed in these areas, additional product areas may be selected for issuance of guidelines.

Some commenters suggested additional product areas which EPA should include in this and/or future guidelines. These products include petroleum products, petrochemicals, waste oil, metals, glass, tires, polyester bottles, salvaged materials, wood ash or coal/wood ash, and lead blast furnace slag.

These comments were not accompanied by any documentation as to how they meet the criteria for selection of product areas, as EPA specifically requested in the preamble to the proposed guideline. No information was presented as to why these products are good candidates for the procurement guidelines program. However, EPA has studied or considered some of these product areas for the issuance of guidelines. The only currently viable candidate on the list appears to be waste oil, i.e., Federal purchasing of rerefined oil. A guideline may be issued for this product area after completion of the already planned guidelines mentioned above.

Two major categories of metals, aluminum and ferrous scrap, have been considered for procurement guidelines and rejected. Aluminum does not constitute a significant solid waste management problem. Recycling programs implemented by the major aluminum producers during the past decade have had a significant impact on the major source of aluminum scrap—the aluminum can. So valuable has this material become that its price has risen well over 100% during the past five years. Federal involvement would do little to promote further aluminum recycling, where the marketplace has already responded based on economics.

With regard to recycling ferrous scrap, although it is certainly technically and economically feasible, EPA has determined that the Federal government possesses very little ability to influence the amount of scrap which is currently recycled, through the procurement guidelines program. One reason for this is the technical capability of steel furnaces to use scrap. Basic oxygen and electric-arc furnaces currently are operated very close to their maximum technically feasible scrap utilization levels. The open hearth furnaces, on the other hand, have the capability to use additional amounts of scrap. This has been demonstrated in the past, where scrap has served essentially as the surge material when demand for steel increases. However, open hearth furnaces are slowly being phased out and replaced by basic oxygen and electric-arc furnaces. Open hearth furnaces account for less than 15 percent of domestic steel production today, compared to over 40 percent in 1969. Any expansion of production in the steel industry will take place by way of electric-arc and basic oxygen furnaces, which technically must use certain levels of scrap. Thus, Federal involvement would do little to promote further recycling of this material.

A second major reason for not issuing a guideline for ferrous metals is the number of distribution levels through which steel products must pass before receipt by the government. The criterion that the Federal government be in a position to affect purchasing of a recovered material product depends very much upon how directly the government can deal with the manufacturer of the product. For most of the products EPA has considered for the issuance of guidelines, the government purchases directly from the manufacturer or at most, from one intervening level. Although the government purchases such steel-containing products as automobiles, desks, and file cabinets, these are obtained from the final product manufacturers or distributors, very far removed from the steel production process. It is unlikely that the Federal government could influence raw materials utilization practices of steel manufacturers, with such reduced leverage, or obtain meaningful certification of recovered material content.

With regard to government purchases of products containing recovered glass, the above discussion regarding levels of distributors applies here. The government purchases fabricated products which contain glass as one component or are packaged in glass. However, the government possesses very little leverage over the raw materials utilization decisions of glass manufacturers in such situations. There are some potential uses of recovered glass in construction products, such as in brick manufacture or as an aggregate in concrete block or in asphalt concrete. However, these applications have not yet proven themselves to be technically or economically viable enough to be commercially available for the purpose of Federal procurement.

Another waste material, tires, has potential for utilization. One promising application is the use of crumb rubber from waste tires in an asphalt-rubber mixture in highway construction. Such uses are referred to as stress absorbing membranes, involving a thin layer of asphalt-rubber used as surface material with chip seals or as an interlayer with a surface overlay. Asphalt-rubber has been demonstrated to be effective in preventing certain types of pevement cracking by improving the elasticity of the pavement and reducing the susceptibility of the pavement to temperature changes. However, technical feasibility and availability have not yet been demonstrated in wide areas of the country. Further, on an initial cost basis, asphalt-rubber systems appear to be more expensive than conventional pavements, although on a life-cycle cost basis asphalt-rubber may be less expensive. Insufficient data at the present precludes accurate cost comparisions.

This product area is one for which EPA may issue a procurement guideline in the future, as technical, economic, and availability factors are resolved. In the meantime, agencies responsible for highway construction programs at the Federal, State, and local level are urged to investigate the potential for use of asphalt-rubber through further demonstrations and evaluations in their particular regions.

With regard to using salvaged materials, i.e., used brick, old concrete crushed for aggregate, etc., no procurement guidelines are currently envisioned. Construction debris such as this has not been demonstrated to be a significant solid waste problem. This generally inert material is usually disposed of on contractor-owned land and not in municipal landfills where it would consume sorely needed landfill space. Further, reuse of such materials, while potentially very desirable, is likely confined to project specific situations which lend themselves to this practice.

The suggestion for using wood ash or combinations of coal ash and wood ash for concrete, in similar fashion to fly ash from coal combustion, is not considered legitimate. It fails to recognize that fly ash must possess certain chemical and physical properties in order to react successfully in a concrete mix. While no documentation was provided, it is highly unlikely that wood ash or coal/wood ash possess these same properties.

Rationale for Choosing To Issue Guideline Pertaining To Fly Ash

Fly ash used in cement and concrete was chosen as a product area where Federal purchasing power could significantly increase the use of a recovered material. The following discussion demonstrates that fly ash meets the product selection criteria.

(1) Significant Solid Waste Problem

Fly ash is the term used to describe an ash component of coal which results from the combustion of coal. The vast majority of fly ash is produced in electric power generating plants, where powdered coal is burned to produce steam to drive the turbines. Fly ash, which is a finely divided mineral residue, is conveyed out of the boiler along with the stack gases. It is then collected from the gases by various means, including electrostatic precipitators, mechanical precipitators, cyclone separators, bag houses and scrubbers. It is stored in silos, awaiting reuse or disposal, or it may be conveyed directly to a disposal area. Fly ash typically represents about 70 percent of the ash generated by coal combustion, with coarser and heavier bottom ash accounting for the remaining 30 percent.

During 1979, 57.5 million tons of fly ash were generated, with over 82 percent disposed of as waste. The quantities of fly ash requiring disposal will increase dramatically during the 1980's with the construction of additional coal burning power plants. Estimates are for fly ash generation to be 70–80 million tons annually by 1985.

Current disposal practices for fly ash can have a negative effect on water quality (surface and groundwater contamination), air quality (increased dust), land use, noise, and aesthetic value.

(2) Feasible Methods of Recovery

Economically feasible methods exist for recovery of the fly ash waste stream. Electrostatic precipitators or mechanical collection devices separate fly ash from boiler stack gases. More than two-thirds of the coal-fired generating stations have collection and loading facilities for fly ash. However, the majority of fly ash currently is combined with bottom ash, boiler slag, and/or scrubber sludge for disposal, making future recovery for cement and concrete use difficult and more expensive.

(3) Technically Proven Uses

Cement is a powder-like manufactured mineral product, usually gray in color. Cement is mixed with water and sand, gravel, crushed stone, or other aggregates to form the hard substance known as concrete. Cement is not used by itself for construction but is a component of concrete.

Cement is produced by first grinding a carefully proportioned mixture of raw materials such as limestone, silica, sand, clays, and iron ore. The mixture is heated in huge rotary kilns at temperatures approximating 1500°C (2700°F), where chemical reactions take place. The resulting marble-size pellets, or clinker, are ground with a small amount of gypsum (to control setting and hardening) to produce an extremely fine powder, known as "portland" cement. Portland cement is a generic term used to describe a particular type of inorganic hydraulic cement. A hydraulic cement is a cement which will combine with water and harden.

a. *Raw Material.* Several commenters pointed out that fly ash can be used as a raw material in the initial production stages of cement. Fly ash can be a source, for example, of iron and silica needed for cement manufacture. As such, fly ash can be used as a supplementary raw material feedstock which is proportioned with other raw materials and burned in the kiln to form clinker, which is then ground to produce cement.

Fly ash used in this manner loses its identity and becomes an integral part of the cement. Portland cement from such production is tested and certfied according to ASTM standard C150 prescribed by the American Society for Testing and Materials. It is stored, transported, marketed, and used in the same manner as cement produced without using fly ash as a raw material. Such cement is generally not identified as being produced from fly ash.

Fly ash used as a raw material completely loses its identity by undergoing chemical reactions with other cement constituents, allowing further amounts of fly ash to be incorporated into the cement, either to produce a blended cement containing fly ash, or as an admixture in concrete, as discussed below.

Although EPA strongly encourages the use of fly ash as a raw material in the production of cement, we feel it is unnecessary to recommend any changes in specifications, purchasing practices, or certification procedures for this application. The standard specification for portland cement, ASTM C150, currently allows for fly ash use in this manner. Solicitations typically request ASTM C150 as the controlling specification. Standard certification practices exist in the industry. Further, the extent to which fly ash can be used as a raw material is highly plant-specific, depending upon the mineral resource needs of any particular manufacturing plant. Thus, no Federal intervention is deemed appropriate for this application.

b. *Blends and Admixtures.* Although not cement itself, fly ash has the property of cementation when combined with lime and water, and this can complement the cementing action of portland cement. Fly ash combines with the water-soluble lime generated during the reaction of portland cement with water, and forms insoluble cementitious compounds. This cementitious property gives fly ash two primary uses: as an ingredient in blended cements, and as a component of portland cement concrete. When used to produce blended cement fly ash is either interground with the portland cement clinker, or blended with the finely ground portland cement powder (or both). When used directly in concrete, fly ash is added to the standard concrete ingredients at the concrete mixing site. Fly ash can be used either as a partial cement replacement in concrete, or as an added ingredient to obtain certain desired concrete characteristics. Almost 3 million tons of fly ash were used in the production of cement or concrete during 1979.

1. *Blended Cement.* Several U.S. cement manufacturers produce a blended cement meeting the standards prescribed by the American Society for Testing and Materials (ASTM) for the use of fly ash in cement. Blended cement containing fly ash is included in ASTM specification C595 and is designated as "Type IP" or "Type I(PM)." Table 1 indicates the extent to which Type IP or Type I(PM) cement can be used as a substitute for ASTM cement Types I through V in general concrete construction.

TABLE 1

ASTM Cement type	Purpose	Substitute fly ash
I	General purpose	Yes.
II	Moderate sulfate resistance and heat of hydration.	Yes.
III	High early strength	No.
IV	Low heat of hydration	Yes.
V	High sulfate resistance	Yes.

2. *Concrete Admixture.* Fly ash can also be used directly as an admixture in concrete, as a partial replacement for portland cement. ASTM specification C311 contains requirements for the sampling and testing of fly ash when in this manner. ASTM C618 is the standard specification for the use of fly ash as an admixture in concrete. In addition, the General Services Administration maintains Federal Specification SS-C-1960, which references ASTM C618, with minor differences for sulfur trioxide content, loss on ignition, and the pozzolanic activity index.

c. *Bottom Ash.* Bottom ash is the term used to describe an ash component of coal which results from the combustion of coal. The ash that is not fine enough to go up the stack with boiler gases in the form of fly ash instead solidifies and agglomerates into coarser heavier particles. These coarse particles fall into the ash hopper at the bottom of the furnace. The ash may be generated in a dry state or in molten form, where it is more accurately referred to as boiler slag.

Commentars stated that bottom ash and boiler slag can be used in the production of Type IP, portland-pozzolan cement. The cement is apparently marketed as Type IP and certified in accordance with ASTM C595. In this application, the ash is generally interground with cement clinker to produce blended cement. This application is possible because bottom ash is very similar to fly ash in chemical composition.

EPA feels it is inappropriate to include, at the present time, bottom ash or boiler slag as used in the production of Type IP cement, as a recovered material which is "designated" under this guideline. Although bottom ash and boiler slag generally meet the criteria discussed here as those criteria relate to fly ash, the recommendations which EPA makes in this guideline regarding specification and purchasing of Type IP cement are based solely on investigation related to fly ash. Because this is a relatively minor application at the present time, and in order to minimize confusion, the Agency has not included bottom ash and boiler slag as "designated" materials in § 249.02 of the guideline. However, although the guideline language will continue to reflect emphasis on the use of fly ash, procuring agencies should be receptive to consideration of such bottom ash use, when it arises.

d. *Practical Applications.* Many ready mixed concrete producers and concrete product manufacturers have used fly ash for years, particularly in non-specification jobs where they are responsible for the performance of the product, but are able to choose the material content which will best suit their needs both technically and economically.

Several commenters provided EPA with names of specific projects or types of applications where fly ash has been used successfully in concrete. EPA feels that mention of these applications will be particularly useful to potential users of fly ash, particularly those who may possess doubts as to the legitimacy of using fly ash in concrete. The following list is by no means exhaustive, but indicates general areas where fly ash has been used on a commercial scale.

1. *Structural Building.* Structural concrete containing fly ash has been used extensively in certain regions of the country. Buildings in the Chicago area which contain fly ash include the Sears Tower, John Hancock Center, McCormick Place, Standard Oil Building, Prudential Building, Inland Steel Building, and First Wisconsin National Bank of Milwaukee. Other buildings include the Detroit General Hospital, the Atlanta Hilton Hotel, and the Davis-Bessie nuclear power plant near Toledo, Ohio.

2. *Wastewater Treatment Plants.* Locations of more than a dozen wastewater treatment plants, where concrete containing fly ash was utilized, were provided by commenters. These plants included both municipal and industrial treatment plants. Fly ash is sometimes specified or allowed for use as an alternate to ASTM Cement Types II or V, due to the often improved sulfate resistance which concrete containing fly ash can afford.

3. *Dams.* On a national level, the U.S. Army Corps of Engineers and U.S. Bureau of Reclamation have used fly ash in concrete in various projects, most notably dam construction, for many years. Some of these projects include:

Hungry Horse Dam—1953
Dworshak Dam—1973 (700' high)
Libby Dam—1975 (400' high)
Richard B. Russell Dam—under construction
Tombigbee Riverway—under construction (series of locks and dams)

A new project on which fly ash is permitted in concrete is the Central Arizona Project, designed to convey water from the Colorado River to the cities of Phoenix and Tucson. The $2 billion project involves construction of over 300 miles of concrete aqueduct and four large pumping stations.

4. *Pavement.* Some State Departments of Transportation have approved fly ash use. For example, the Georgia Department of Transportation (DOT) revised its specifications in 1975 to allow fly ash to be used as a partial cement replacement. Since then, Georgia's DOT has placed over three million cubic yards of fly ash concrete pavement and road shoulders, and is now considering review of the specification to allow for a greater fly ash replacement rate.

5. *Concrete Block.* Many manufacturers of concrete block use fly ash at rates of 20–35% of total cementitious material. Some manufacturers use as much as 50% fly ash when employing high-pressure-steam cured processes.

6. *Concrete Pipe.* Some concrete pipe manufacturers use fly ash to obtain a better material flow in production, and to increase the density and decrease the permeability of their product.

e. *Performance of Fly Ash.* Some commenters pointed out that a distinction should be made between ASTM Class F ashes, obtained from the combustion of bituminous coal, and the ASTM Class C ashes, which are obtained from subbituminous and lignite coals. While both types of fly ash are composed of the same chemical components, the quantity of these chemical components as constituent elements of these two types of fly ash vary. The proposed preamble was primarily limited to a discussion of Class F ash, although some of the statements may be true for Class C. The following discussion has been revised to reflect the differences in performance of the two types of ash where information was available from commenters.

1. *Enhanced Performance.* As discussed in the proposal, the use of fly ash in cement and concrete may enhance the performance characteristics of the final products.[1] These advantages can be summarized as follows:

i. *Greater Ultimate Strength.* Proper mix design will achieve 28-day strength equal to or better than a typical Type I cement. Fifty-six day strength will be superior in almost all cases. In the examples of structural applications listed above, use of fly ash was found to be the most practical and economical method of obtaining high strength mixes.

Class C ash concrete may attain early strengths equal to or greater than concrete utilizing portland cement only. This is likely due to the higher calcium oxide content of Class C ash, leading to more rapid development of cementitious compounds.

ii. *Improved Workability.* Specification fly ash used in properly proportioned concrete mixes improves the pumpability, handling, placing, and finishing of fresh concrete, in part due to the glassy, spherical shape of fly ash particles, which add to the "plasticity" of the mix.

iii. *Reduced Water Requirement.* Due to improved workability, usually less water needs to be added to the mix, resulting in less drying shrinkage and less cracking.

iv. *Lower Heat of Hydration.* Generally, less heat is generated during the chemical reactions between the cement and water, resulting in less thermal cracking—especially important in mass concrete applications such as dams, large beams, retaining walls, and foundations.

When using Class C ash, however, the prolific cementitious reactions which take place due to higher calcium oxide contents may not allow for achievement of lower heat of hydration. This characteristic of Class C vs. Class F should be noted where heat liberation is critical.

v. *Increased Sulfate Resistance.* A proper concrete mix with Class F fly ash will reduce the chemical attacks in concrete from sulfates contained in adjacent soil and groundwater. These reactions cause cracking and eventual disintegration of the concrete. Fly ash forms stable cementitious compounds with certain cement constituents, thus reducing the ability of sulfates to combine with these same cement constituents.

With Class C ash, there apparently is no improvement in sulfate resistance. One commenter claimed that subbituminous and lignite fly ashes generally lead to reduced resistance to sulfate attack in concrete.

vi. *Reduced Alkali-Aggregate Reactions.* Certain aggregates react with the alkalis generated during cement hydration, resulting in disruptive expansion and cracking of concrete. Class F fly ash reacts with these alkalis to form stable compounds, thus preventing or severely reducing the reaction with aggregates and the accompanying detrimental effects.

Commenters on Class C fly ash state it has negligible effect with regard to alkali-aggregate reactions. In any event, standard tests are available to determine if a reaction is likely to occur. This likelihood can be predicted as accurately with fly ash as with portland cement.

2. *Disadvantages.* Several disadvantages which are associated with the use of fly ash can be overcome through proper use.

i. *Variable Physical and Chemical Composition.* Fly ash from different sources can be highly variable in its physical and chemical composition. This variability can be due to several factors, such as coal source, combustion process, and collection method. This problem can be overcome through adequate testing and quality control of the ash. ASTM specifications C595, C311, and C618 should be used as minimum standards for acceptance of fly ash. However, these material standards by themselves will not guarantee satisfactory performance of a concrete mix, just as use of portland cement conforming to ASTM C150 will not assure production of a satisfactory concrete. Proper mix design, selection and quality control of all materials, and expertise in mixing, placing, and finishing of concrete all play a role in achieving satisfactory performance.

The issue of ash variability and quality control was by far the technical issue of most concern to commenters. Many commenters who stated that use of fly ash results in deleterious performance of concrete based their concerns on situations where low quality, non-specification ash might be used in concrete. EPA agrees in principle with these commenters concerns. Therefore, EPA substantially revised the sections of this preamble and guideline entitled "Quality Control," which emphasize the need for quality control and quality assurance procedures on the part of all involved parties, particularly fly ash suppliers and material vendors.

ii. *Unfamiliar Users.* Due to lack of widely publicized and sometimes inadequate data on mix designs (as compared to general purpose concrete), fly ash concrete may be improperly prepared by an unfamiliar user. Mix designs do exist to produce fly ash concrete, and in most cases fly ash brokers/companies will provide manufacturing assistance and engineering design aid. The "References" section of this guideline refers to information on fly ash and its use in cement and concrete. Potential users should familiarize themselves with

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[1] (The properties of cement and concrete which contain fly ash have been examined and documented. A report by the National Bureau of Standards entitled "Fly Ashes in Cements and Concretes: Technical Needs and Opportunities," NBSIR 81-2238, summarizes these properties.)

the information in those publications, [illegible] seek assistance from suppliers of fly [illegible]

iii. *Special Storage and Transportation Equipment.* Due to its extreme fineness, fly ash requires the use of storage and conveying equipment with tight fittings. Equipment meeting these requirements is readily available.

iv. *Extended Curing Time.* Mix proportions have been developed which will achieve equal or superior strength to general purpose concrete at all ages, particularly if 10%–30% fly ash is added (not substituted) to a concrete mix, or if a blended cement with up to 10% fly ash content is used. However, when used as a cement replacement, superior strength is often not achieved until the age of 28 days.

As discussed earlier, commenters using Class C ash state that equal or superior strength gains can be achieved at all stages of development.

v. *Increased Demand for Air Entraining Agent.* Inadequate air content in concrete will significantly affect its durability and most likely result in premature deterioration. Fly ash used in blended cements and concrete will often cause an increased demand for air entraining agent. With [illegible]per testing and quality control, the [illegible]l for entrained air can be satisfied. [illegible]e cost of the additional air entraining agent and quality control is often balanced by the cost savings associated with fly ash use.

Commenters on Class C fly ash indicate that air entrainment is not a problem, due to the lower loss on ignition (LOI) of Class C ashes compared to Class F. The reason for a low LOI is likely not due to any inherent property of lignite or subbituminous coal. Rather, these coals are often burned in newer, more efficient, power plants, resulting in more complete combustion with less residual carbon. One the other hand, many of the power plants in the East burn bituminous coal. These plants are generally older and may combust less efficiently than the generally more modern plants found where the lignite and subbituminous coals reserves are located.

EPA cautions against making air content determinations based on the class of ash. Rather, marketers and users should be concerned with the properties of the particular ash at hand. Both types of ash, regardless of carbon level, can affect air entrainment levels and should be evaluated vis-a-vis [illegible]pensating air entraining admixture [illegible]els. This is because any alteration in the mix properties affecting the fine aggregate particle distribution and heat evolution has an effect on air entrainment.

(3) Federal Purchasing Power

Almost one-half of total U.S. cement consumption is in public construction projects (public buildings, public works, transportation). Since Federal funds account for nearly two-thirds of the funding for public construction nationally, approximately 23 million tons of cement is purchased annually either directly or indirectly with Federal funds. These 23 million tons mark the theoretical universe to which this guideline applies.

The actual figure may be lower, however, as some of these cement applications may not be technically appropriate for the use of fly ash. In addition, some of these Federally funded projects already incorporate fly ash. On the other hand, with the anticipated "ripple effect" of private purchases being influenced by these public purchases, the impact could be substantially increased. For example, commenters indicate in those areas where fly ash is accepted, contractors who use fly ash will tend to use it for all of their projects, public and private, where technically acceptable.

Discussion of Guideline

This section of the preamble summarizes and explains the guideline and its integration with the requirements of Section 6002 of the Act. The guideline recommends practices with regard to specifications, purchasing, and certifications which procuring agencies may employ in complying with the mandatory provisions of Section 6002. Adherence to the procedures suggested in the guideline will be deemed to constitute compliance with Section 6002.

Scope

The scope of this guideline is limited to the use fly ash in cement and concrete, including concrete products such as pipe and block. Several commenters agreed with this limitation. However, as discussed in this Preamble under the section entitled "Technically Proven Uses," commenters indicated that bottom ash and boiler slag are being used in production of Type IP, portland-pozzolan cement. Therefore, when reference is made in this guideline to Type IP or blended cements, bottom ash and boiler slag should be considered by procuring agencies as qualifying for those applications, if manufacturers/suppliers can provide satisfactory technical support.

Many commenters pointed out that fly ash and bottom ash can also be used in many other construction applications, such as road base and subbase material, structural fill and embankment, soil stabilization, grouting, masonry cement, and as lighweight aggregate. However, the technical and economic issues related to these uses of coal ash are sufficiently different to warrant separate consideration by procuring agencies. The Agency intends to prepare guidelines on a product-by-product basis.

Guidelines on the use of fly ash in road bases and subbases are currently being drafted by EPA. The Agency believes such use can result in significant economic and energy savings nationwide. Interested persons should become aware of the recently enacted Federal Highway Administration demonstration program (Project 59) for fly ash in highway construction.

The fact that EPA has not issued guidelines for certain applications of fly ash should not be construed as preventing agencies from investigation and use of such materials. For example, one commenter indicated a history of successful use of fly ash in producing a masonry cement meeting the requirements of ASTM, C91, Standard Specification for Masonry Cement. Such uses are encouraged. Agencies should apply the general provisions of this guideline to such applications, in keeping with the intent of RCRA.

The Agency received comments on and considered expanding this guideline to include the use of granulated iron blast furnace slag in cement and concrete. Although major actions have recently been taken to increase the quality and quantity of granulated slag, EPA does not believe granulated slag is sufficiently available yet to warrant guidelines on a national scale. In addition, iron blast furnace slag is already reused at a very high rate, as aggregate and as fill material. Procuring agencies are strongly urged to apply the general provisions of this guideline in those cases where granulated slag suitable for use in cement becomes available.

Similarly, silica fume, the by-product dust resulting from the manufacture of silicon metal and collected in air pollution control devices, has been studied for its use in cement and concrete. The U.S. Army Corps of Engineers has developed results which indicate that silica fume can be extremely beneficial in increasing the resistance of concrete to sulfate attack, while generally maintaining early strength similar to that of portland cement concrete that does not contain the dust. However, additional technical information and standards need to be developed before this material is used on a national scale. Thus, a specific procurement guideline is not currently envisioned for silica fume.

In the meantime, agencies should apply the general provisions of this guideline in those cases where silica fume or other recovered materials become available. This guideline should not be construed as preventing the procurement of other recovered materials suitable for use in cement and concrete.

Some commenters questioned why the use of shales and other naturally occurring pozzolans is not addressed by this guideline. Because the philosophy of the procurement guidelines program is to encourage recovery and reuse of solid waste materials, consideration of guidelines for natural materials which are not solid wastes is inappropriate.

One commenter suggested that EPA disallow the use of concrete containing fly ash in load bearing structures. In view of the successful structural applications mentioned elsewhere in this guideline, and with no documentation provided by the commenter to support the suggestion, EPA must reject it.

Several commenters requested that EPA exempt precast and prestressed concrete products from the guideline. The main concerns expressed by these commenters were that use of fly ash would cause delays in production of these products resulting in increased costs and loss of competitive edge vis-a-vis substitute products. Commenters stated that energy consumption would increase as a result of raising curing temperatures to achieve needed early strength gains. These commenters also expressed concern over the quality and variability of fly ash, which can affect performance and color of precast and prestressed concrete products.

The basis of these commenters' concerns stems from resistance to "mandatory" use of fly ash, i.e., a recommendation contained in the proposed guideline that procuring agencies solicit bids solely for cement or concrete containing fly ash when, in their judgement, those products were available, cost competitive, and technically acceptable. The commenters claimed this recommendation caused confusion and would lead to blanket requirements that fly ash be used in all precast and prestressed products.

EPA has deleted this recommendation in the final guideline, in favor of an approach which recommends that fly ash use be included in all solicitations, unless technically inappropriate. EPA believes that there are no good grounds for exempting precast and prestressed concrete products from such solicitations. Several commenters stated that fly ash is currently being used by some manufacturers of precast and prestressed concrete, apparently with technical and economic success. EPA believes that persons who are willing and able to use fly ash, while guaranteeing performance of their product, should have the opportunity to do so. Thus, an exemption for this product area is not considered appropriate.

Applicability

The requirements of Section 6002 apply, for the most part, to "procuring agencies." The term "procuring agency" is defined by the Act as "any Federal agency, or any State agency or agency of a political subdivision of a State which is using appropriated Federal funds for such procurement, or any person contracting with any such agency with respect to work performed under such contract." The affirmative purchasing requirements of Section 6002 apply to procuring agencies' purchases exceeding $10,000, or where that quantity of functionally equivalent purchases in the preceding fiscal year exceeded $10,000.

This guideline recommends that any solicitations for purchases of cement or concrete made with Federal funds, either directly or indirectly, specifically allow for fly ash to be used as an optional or alternate material, unless it can be shown that the use of fly ash is technically inappropriate for a particular construction application.

(1) Procuring Agency

(a) *Direct purchases.* With regard to direct purchases, there are several situations to which the Agency believes this guideline should apply. Although the language on applicability in Section 6002 leaves room for interpretation, the Agency believes the recommendations here best describe the intent and practical application of Section 6002.

The first is where a Federal agency or other authority using Federal funds purchases cement, either in bag or bulk form. The agency may use this cement or it may supply the cement to other persons or the cement may be used by persons performing construction services for the agency. An example of this occurs where the Department of Defense, Army, purchases cement for use on a construction job, or its general contractor or subcontractor purchases cement for use on that job.

A second case occurs where ready mixed concrete is purchased directly by a Federal agency. The same scenarios applied to direct purchases of cement apply here. If a Federal agency purchases ready-mixed concrete for its own use or, more likely, if a person under contract to or in support of a Federal agency purchases concrete, then the provisions of this guideline apply.

(b) *Indirect purchases.* Indirect purchases of cement and concrete by Federal or other procuring agencies are subject to this guideline. This is where the coverage of the term "procuring agency" becomes critical. Foremost among indirect consumers of cement and concrete are the Department of Transportation (including the Federal Highway Administration, Federal Aviation Administration, Urban Mass Transit Administration); the Department of Health and Human Services; the Department of Housing and Urban Development; and the EPA itself (wastewater treatment works construction grants program). All these agencies are involved in the Federal funding of construction programs for or through state and local governmental authorities. EPA believes that any purchase of at least $10,000 worth of cement or concrete by States and localities or their contractors, subcontractors, grantees or other persons which is funded by grants, loans, funds or similar forms of disbursements of monies from Federal agencies is subject to the provisions of this guideline.

EPA recognizes that these cases of indirect Federal funding may present the most difficulty for implementation. For instance, while the Federal Procurement Regulations and the Defense Acquisition Regulations control all Federal agencies in the case of direct procurement, each Federal agency establishes its own grant regulations. In addition, agency reviews appear to exert little influence over the composition of materials used in construction activities funded by that agency. An agency's primary interest is that the project performs as intended.

While some commenters expressed support for the above interpretation, other commenters had very differing viewpoints. One commenter, the Federal Highway Administration (FHWA) agreed that its direct procurement program for Federal roads and highways is subject to RCRA Section 6002 requirements. The direct-Federal program includes highway projects on Federally owned lands, such as national parks.

However, the FHWA has taken exception to the inclusion of the multi-billion dollar Federal-aid (Federal Highway Trust Fund) program under Section 6002. FHWA contends that State highway departments operating under

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the Federal-aid program are not procuring agencies under RCRA because they use State funds rather than appropriated Federal funds for any necessary procurement. A percentage of their expenses is later reimbursed by FHWA if the States have satisfactorily complied with applicable Federal laws, regulations, and FHWA/DOT policies. Thus, FHWA states that guidelines promulgated by EPA are not applicable to the Federal-aid program.

EPA does not agree with the above FHWA interpretation. Although the Trust Fund monies result from the Federal excise tax on gasoline, the monies are appropriated to projects before they are redistributed to the States. Further, these Federal funds are substantially being used for procurement of the highway projects in question. Long-established relationships indicate that States are virtually guaranteed of receiving the Trust Fund monies as long as their projects are approved by FHWA and they comply with the requirements specified by FHWA.

EPA does not believe that the legislative history of RCRA supports such a narrow interpretation of the term "procuring agency." Rather, the intent of RCRA Section 6002 is to use the influence which the Federal government can exert through its purchasing power to stimulate demand for and use of recovered materials. Therefore, EPA is of the opinion that the Federal-aid program for highway construction projects is subject to RCRA requirements. Those persons who believe they will suffer damage as a result of failure by a procuring agency to comply with Section 6002, are urged to review the section of this preamble entitled "Compliance and Monitoring."

(c) *Unrelated purchases.* One commenter suggested a very strict interpretation of the term "procuring agency." This commenter claimed that once an agency uses any Federal funds for any procurement (over $10,000 total), *all* purchases (including non-designated items and those made with non-Federal funds) by it and any entities contracting with it become procuring agencies within the meaning of RCRA.

EPA disagrees with this interpretation. In the statute, Congress defined procuring agency to mean an Agency which "* * * is using appropriated Federal funds for such procurement," thereby signalling an intention to exclude purchases made with non-Federal funds from the explicit reach of Section 6002.

Further, the RCRA amendments, discussed elsewhere in this preamble, key the purchasing requirements of Section 6002 to the "designation" by EPA of certain candidate products by way of procurement guidelines. These amendments were passed, in part, because procuring agencies were pursuing inconsistent policies in attempting to implement RCRA purchasing policies throughout their procurement systems for all of their products. EPA is now given the responsibility for designating those items whose procurement will best carry out RCRA objectives.

Thus, this guideline should not apply to construction activities being performed which are unrelated to or incidental to Federal funding, or which include purchases on non-designated products. An example of an activity unrelated or incidental to Federal funding would be where a contractor performed laboratory experiments and bench-scale tests for the Government under a contract. In order to carry out his responsibilities he may need to expand his existing physical facility or construct a new one. The cement and concrete used in that structure would not be subject to the requirements of Section 6002 or this guideline, even though some of the funds received from Federal contract payments might be used to finance the construction.

Another commenter suggested regional instead of nationwide guidelines. The reason cited was that fly ash of the quality and quantity required for a construction project may not always be immediately available in certain parts of the country. Another commenter requested an exemption for city and county construction projects, citing a lack of expertise on their part.

These two comments serve to emphasize the "chicken and egg" dilemma for many recycled materials. Is fly ash not available because there is no demand or expertise to use it in a particular area, or is there no demand or expertise in those areas because fly ash is unavailable? The purpose of this guideline is to alter the status quo by stimulating demand for fly ash, thereby encouraging its availability and the development of the necessary expertise. EPA feels that by including fly ash in bid solicitations as an alternate or optional material, availability will be determined by whether any bids are received for it. Further, allowing for fly ash use will serve as an incentive to potential users in these areas. Contractors will not make the commitment necessary to use fly ash unless it is more readily accepted. Specifically allowing it to be used provides this incentive.

(2) $10,000 Rule

An important issue is the applicability of the $10,000 rule. Clearly, the guideline applies where a procuring agency directly purchases more than $10,000 worth of cement or concrete during the course of any fiscal year. The rule is complicated, however, if a procuring agency purchases concrete "services," which would not only involve the supply of the product but also placement, finishing, etc. Even more complex is the common case where a contractor is assigned all construction activities for a particular agency project, including subcontracting authority for concrete work. In such cases the actual cost of the cement or concrete may not be readily determinable.

In the proposed guidelines, EPA recommended that the $10,000 limitation include the cost of services related to the purchase of the product as well as to the cost of the product itself, at least in those cases where the separate cost of the materials cannot be practically determined.

EPA received several divergent comments on the issue of including concrete "services" in determining applicability of the $10,000 rule. An equal number of commenters agreed and disagreed with this approach. EPA's purpose in including services in the $10,000 limitation as stated in the proposal, was to allow flexibility to procuring agencies and reduce paperwork which might otherwise occur. The final guideline now leaves it at the discretion of an agency as to whether that agency chooses to separately cost-out all the elements of concrete work for purposes of determining RCRA applicability. In some cases, this calculation may be a simple task, particularly for direct purchases of concrete. On the other hand, it may be virtually impossible to obtain such detailed cost information where a general contractor has responsibility for all work on a project. Agencies may desire to establish procedures for estimating the proportion of a project which is represented by the material costs of cement and concrete.

In any event, EPA urges that agencies keep in mind the intent of RCRA, i.e., increased use of recovered materials, in developing their approach to determining RCRA applicability. Imposition of new paperwork or estimation procedures for this purpose should be avoided. Rather, EPA recommends that fly ash use be specifically allowed in *all* cases, except where technically inappropriate. EPA recommends that agencies develop and issue policies to their construction directorates, field offices, grantees, etc. on this issue so that consistency will be maintained in applying this provision.

On a related topic, several commenters stated that the $10,000 limitation was to low, because, it would subject too many small jobs to Section 6002 requirements. EPA cannot accept the commenter's rationale. Congress established the $10,000 purchasing rule in Section 6002(a) of RCRA. The reason for setting a minimum was most likely so that incidental purchases would not be subject to specification changes purchasing requirements, and monitoring efforts. Furthermore, the $10,000 limitation is not to be considered on a contract-by-contract basis, but rather is an aggregate total for the cost of cement and concrete materials during a fiscal year. In order for cement and concrete containing fly ash to be assimilated into the construction materials procurement system, it needs to be considered as an acceptable material on a regular, day-to-day basis. Fly ash should not merely be reserved for larger dollar value projects, as one commenter suggested.

Definitions

Of the definitions which were contained in the proposed guideline, most were self-explanatory and non-controversial and therefore need not be addressed in this preamble. In addition to the definition of "procuring agency" discussed above, the terms "recovered material" and "solid waste" deserve discussion, as EPA received comments on these particular definitions.

The requirements of Section 6002 apply to products containing recovered materials. The definition of "recovered material" contained in the proposed guideline was the same as that in RCRA. However, the definition of recovered material was revised by Congress in the Solid Waste Disposal Act Amendments of 1980. The current definition includes waste material and by-products which have been recovered or *diverted from* solid waste. It excludes materials and by-products—such as home scrap—generated from and commonly used within an original manufacturing process.

Some commenters argued that materials which were being recycled were not solid wastes, because they were not being discarded. The Agency has already dealt with this argument on numerous occasions (see, e.g. 45 FR at 33091 (May 19, 1980)). We think it clear from the language of the statute, the legislative history, judicial interpretation, and subsequent expressions of Congressional intent that Congress intended that materials being used, reused, recycled, or reclaimed be solid wastes. These activities are types of waste management which, if properly conducted, can avoid environmental hazards, protect scarce land supply, and reduce the nation's reliance on foreign energy and materials.

Some commenters on this guideline specifically took exception to the definition of "solid waste" and EPA's authority to regulate reuse and recycling. Rather, they argued that EPA's authority to designate products for procurement guidelines should be based on whether those products are, or contain, recovered materials, i.e., according to the revised definition of "recovered material."

EPA disagrees, in general, with these commenters' opinions. Based on the reasons presented above, EPA maintains its authority to regulate solid wastes which are used, reused, recycled, or reclaimed. In fact, the revised statutory definition of "recovered material" makes clear materials can be recovered from "solid waste," so that the material need not be thrown away to be a solid waste. However, in order to reduce the unnecessary confusion which has arisen in this guideline due to the definition of solid waste, and any revisions to this definition which may occur in the future, EPA has eliminated the definition of "solid waste" from this final guideline.

Specifications

Section 6002(d) of the Act requires revision of all specifications for cement and concrete for which Federal agencies have drafting and review responsibility so that they no longer exclude the use of fly ash—and so that they incorporate the use of fly ash to the maximum extent.

While this requirement applies nominally only to Federal agencies, EPA believes that the elimination of specifications which unreasonably discriminate against the use of fly ash is implicitly required by the affirmative procurement provisions of Section 6002(c) as well. A procuring agency could not realistically fulfill its Section 6002(c) obligation to procure items composed of the highest percentage of recovered materials practicable if, in procuring cement or concrete, it relied upon specifications which unreasonably discriminated against fly ash use. Accordingly, EPA construes the specifications requirement to apply to all procuring agencies.

To assist procuring agencies in achieving compliance with this requirement, the guideline makes several recommendations on specifications. There are three major categories of specifications for which recommendations are made:

- Guide specifications—typically, model standards or specification issued by a procuring agency, which are suggested or required for use in the design of all of the construction projects of an agency (these are often referred to as design standards or design guidelines).
- Contract specifications—a precise set of specifications prepared for a particular construction project, which contains such items as design, performance, and material requirements for that project.
- Material specification—a specification that stipulates the use of certain materials to meet the necessary performance requirements.

Guide Specifications

Procuring agencies will need to review and revise guide specifications in order to reflect the recommendations of this guideline. In doing this, the agencies will need to eliminate any discrimination, either direct or indirect, against the use of fly ash in cement and concrete. In addition they must ensure that guide specifications require that the use of fly ash be considered and incorporated, where appropriate, into contract specifications for individual construction projects. EPA recommends a period of six months after the effective date of this guideline to complete review and revision of guide specifications.

One commenter requested that EPA publish a sample guide specification for use by Federal agencies. EPA has chosen not to follow this suggestion. As mentioned above, guide specifications are usually maintained by individual agencies and can take various forms, such as specifications, standards, or narrative guidelines. It seems undesirable for EPA to develop one guide specification which would be recommended to all agencies. Rather, EPA prefers to allow procuring agencies the flexibility to develop their own specific policies in this area, taking into account types of construction projects, degree of control exercised over specifying architects and engineers, and other such factors. Procuring agencies are expected to reflect the intent of RCRA and policies of this guideline in making whatever changes are necessary in guide specifications.

Several commenters stated that standards of the American Concrete Institute (ACI) currently allow for fly ash use. These commenters specifically mentioned ACI Standard 301, "Specifications for Structural Concrete for Buildings," and ACI Standard 318, "Building Code Requirements for Reinforced Concrete." Such standards apparently do allow for fly ash use, at the descretion of the specifying engineer. However, agencies should still be prepared to make modifications to these and other standards, when and if necessary, particularly if the standards are shown to contain provisions which in some way indirectly discriminate against fly ash use. Specification of minimum cement contents may be one example of such indirect discrimination.

Contract Specifications

This guideline will have its greatest effect on contract specifications which are prepared for each individual construction project. The guideline recommends that agencies make sure that specifications for individual construction contracts specifically include provisions for the use of fly ash as an optional or alternate material, unless it can be shown that this would be technically inappropriate.

Many commenters stated that the most frequent obstacle to fly ash use on an individual project is the specifying architect or engineer. If this person does not specifically allow for fly ash to be used, it is invariably precluded from use. The guideline addresses this problem by apprising procuring agencies that they are responsible for assuring that these individuals are aware of the statutory requirements of Section 6002 and the policies of this guideline with regard to fly ash. Thus, it is critical that the technical officer or engineer on a contract work closely with the contracting or grant officer to assure that fly ash is appropriately considered. The guideline also recommends that procuring agencies document decisions to exclude fly ash from contract specifications, in order to build a base of technical information on this subject, as well as to respond to possible protests or inquiries. Placing the burden upon the procuring agency to assure that fly ash is allowed in contract specifications is particularly important where the design function is outside the agency or where construction projects are being performed as a result of grants, loans, funds, etc.

Several commenters objected to EPA's recommendation that procuring agencies justify exclusion of fly ash from contract specifications, asserting instead that justification to use fly ash should be the subject of documentation. The Agency disagrees with these commenters. Since the technical feasibility of using fly ash in cement and concrete has been adequately demonstrated, agencies should not require a supplier to "reinvent the wheel" for each project. The recommended approach permits fly ash to be evaluated on a job-by-job basis. It doesn't preclude restriction of fly ash as long as it is justifiable and documented. EPA urges procuring agencies to require that individual suppliers of cement or concrete containing fly ash demonstrate a history of satisfactory technical performance with this material and their ability to meet performance requirements for the particular application at hand, just as they would for portland cement or concrete.

Typically, if use of fly ash is not initially allowed, the time period during which bids are officially open is insufficient to allow for consideration of fly ash use and amendment of solicitations. Consideration of changes can often not be accomplished until after the fact, which can lead to contracting problems and invite protests from losing bidders if change orders are issued at a later time without formal resolicitation. Thus, EPA maintains that consideration should be given to using fly ash during development of the contract specifications, and that cement or concrete containing fly ash should be considered acceptable unless the agency demonstrates otherwise.

EPA agrees with a commenter on a related issue, which is that legitimate documentation of infeasibility for fly ash can be for certain types of applications rather than on a job-by-job basis. By referencing this documentation in individual contract specifications, an agency can avoid extensive repetition of previously documented points. An agency should be prepared to submit such documentation to outside review and scrutiny.

EPA recommends that procuring agencies take no more than 12 months from the effective date of this guideline to assure that contract specifications reflect the requirements of Section 6002.

Material Specifications

Both Federal specifications and national voluntary consensus standards exist for the use of fly ash in blended cement and in concrete. Rather than actually revise existing material specifications for portland cement, procuring agencies are expected to make maximum use of these existing material specifications.

In the proposal, EPA recommended that procuring agencies use only fly ash which, as a minimum, meets ASTM standards. Some commenters agreed that use of ASTM specifications as a minimal standard is appropriate, in that they are national voluntary consensus standards which have been developed over a period of time. A few commenters, however, suggested that EPA reference the ASTM standards, but with recommendations for tighter parameters. While EPA discusses such tighter parameters for information purposes in this preamble, the Agency feels it is inappropriate to make recommendations which override national consensus standards.

One commenter requested that compliance with ASTM standards not be made mandatory, because the commenter has been able to use fly ash, which does not conform to the standards in one aspect, very successfully in concrete. EPA agrees with this approach. While the guideline recommends adherence to ASTM and/or Federal specifications, the ultimate determinant of acceptability should be concrete performance. Accordingly, the guideline permits use of non-specification fly ash where the procuring agency has developed sufficient expertise to use it in particular applications.

Mix Design Standards

This guideline suggests no minimum, maximum, or absolute level of fly ash content in blended cement or concrete which is subject to this guideline. Flexibility is necessary because of variation in fly ashes and cements, strength requirements, relative costs, and even local and regional construction practices and climatic conditions.

The provisions of ASTM specification C595 for blended hydraulic cement require that Type IP cement contain 15%–40% fly ash and that Type I (PM) cement contain 0–15% fly ash by weight, thus allowing fly ash content to be specified in a range from 0 to 40%. A typical blending rate in the industry appears to be around 20%. However, the actual proportion to use needs to be determined on a job-by-job basis in accordance with established mix design procedures and performance needs.

When used directly in the manufacture of concrete, industry practice indicates that more fly ash should be use than the amount of cement replaced, at least when using Class F ash. This ratio should be at least 1.25–1.50 fly ash to 1.00 unit of cement. Commenters on Class C ash provided data to indicate that pound-for-pound replacement of cement with fly ash can be used to achieve early strengths equivalent to that of portland cement alone. Typical replacement rates in concrete are around the 15% level, but the actual percentage needs to be determined on a job-by-job basis.

Allowing the use of low levels of fly ash in cement and concrete may encourage additional companies to experiment with the product and gain expertise. This could ultimately increase the number of companies using fly ash, and the amount of fly ash they use.

Information contained in the "References" can be used as guidance in determining proper fly ash content.

While some commenters agreed with this flexible approach to fly ash content and mix design, a few disagreed with it. The dissenters argued that RCRA requires procurement of products containing the *highest* percentage of recovered materials practicable. Thus, if fly ash can be used at a blending rate of 20%, these commenters suggest EPA specify 20% as the minimum level of fly ash content which must be supplied in order to qualify for award.

EPA prefers to interpret RCRA with emphasis on the word *practicable*. EPA feels that the highest percentage of fly ash practicable is determined by such factors as price, availability, competition, and technical performance. For instance, if a higher level of fly ash content is only available at a much higher price, EPA considers it impractical to purchase the higher priced material, although it is technically available. With the open bidding approach recommended in this final guideline, EPA believes that persons willing and able to supply cement or concrete containing fly ash will do so. Normal bid evaluation procedures will then determine practicality based on price, availability, etc. and not on an arbitrarily established limit on fly ash content which considers only technical potential.

Concrete specifications which specify minimum cement contents could potentially discriminate against the use of fly ash. Such provisions may deter substitution of fly ash for cement. To address this problem the proposal recommended changing such specifications to permit the substitution of fly ash for cement.

An equal number of commenters agreed and disagreed on this issue. The opposing commenters stated that minimum cement factors are often based on the need not only for strength but for durability and that an agency should be permitted to specify some level of minimum cement content (which may reflect the substitution of fly ash for a portion of the cement). The commenters were willing to agree with EPA's recommendation on this issue, provided that adequate testing or local experience showed that concrete durability is not affected. EPA feels this is a reasonable approach, and that minimum cement contents may be retained, provided they reflect a substitution of fly ash for a portion of the cement.

Of the commenters supporting EPA's recommendation on minimum cement contents, most stated that minimum cement contents and maximum water:cement ratios discriminate against use of fly ash, and suggested a shift from prescription specifications to those based on performance. A wholesale revision in concrete specifications to those based totally on performance is beyond the scope of this guideline and the jurisdiction of EPA. However, such a shift may be appropriate in particular instances. Thus, this final guideline recommends that procuring agencies change mix design standards which unfairly discriminate against the use of fly ash, such as those which unnecessarily specify minimum cement content or maximum water:cement ratios.

Performance Standards

It is often claimed that designs of construction projects are conservative and, as a safeguard, intentionally increase the strength requirements beyond what the design criteria actually require. Setting concrete strengths which are higher than actually needed during the several days following concrete placement (i.e., "high early strength") can deter the use of fly ash. Although fly ash will generally enable a concrete to achieve a higher ultimate strength (e.g., at 28, 56, and 90 days), very high early strength can be achieved, with Class F ash, only by adding fly ash to the mixture without reducing the cement content. In this situation, the economic and energy conservation advantages of using fly ash are sharply diminished.

In the proposed guideline EPA recommended revising certain performance standards, where appropriate, primarily to extend the period for strength evaluation. Numerous comments were received on this issue, primarily opposing EPA's recommendation. A variety of reasons were given for not extending strength evaluation periods. Foremost among these was a claim that increased costs and delays in schedules would occur as a result of delays in stripping forms or awaiting approval before proceeding with further construction. Some commenters pointed out that strength development is a key factor, in determining durability of concrete. The commenters urged EPA to maintain the current, standard strength evaluation periods, citing their existence as providing a good balance between costs, performance, and timeliness.

Some commenters agreed with EPA's recommendation to extend strength evaluation periods, while others commented this practice should only be allowed for certain applications, such as non-flexural members.

In this final guideline, EPA has retained the general concept that performance requirements which arbitrarily restrict the use of fly ash, either intentionally or inadvertently, should be revised. However, the Agency has removed the specific recommendations for extension of strength evaluation periods. We feel the performance requirements for a project should be assessed based on the specific technical design needs of that project.

The Agency still maintains that a need exists for recognizing that concrete containing fly ash can perform successfully, although it may not always achieve the early strength gains of portland cement concrete. Methods of predicting strength, such as past experience, laboratory design results and accelerated test procedures can be used to estimate the strengths which concrete containing fly ash will attain at specified intervals.

Thus, although concrete containing fly ash may exhibit lower strengths than portland cement concrete, at 3-day and 7-day test periods for example, an agency may consider accepting the product provided the supplier has satisfactorily demonstrated the later day strengths which are expected to be achieved, and the strengths at all ages are satisfactory from a safety standpoint. Of course, in allowing slower early strength development, the contractor is still responsible for performing under the contract in a cost effective, safe, and timely manner. EPA feels this can and is being done.

Purchasing

EPA is designating cement and concrete containing fly ash as a product-area for which procuring agencies must exercise affirmative procurement actions under Section 6002 of RCRA. As discussed in this Preamble under the section entitled "Statute Requirements vs. Guidelines," when EPA "designates" a product area through the issuance of guidelines, RCRA requires that procuring agencies take positive step to purchase that product. This section of the guideline contains recommendations for satisfying the affirmative procurement requirement.

Bidding Approach

In the proposed guideline, EPA recommended that procuring agencies utilize a dual bid approach for cement and concrete purchases. The Agency recommended that all bid solicitations for cement and concrete should solicit bids for both portland cement or concrete and cement or concrete containing fly ash, where technically appropriate. Award would be made to the lowest priced responsible offeror.

In the proposal, EPA further recommended that where the application was technically appropriate and where a procuring agency was satisfied that cement or concrete containing fly ash was reasonably available and its bid price would be competitive with that of portland cement or concrete, only bids for cement of concrete containing fly ash should be solicited. Award would still be made to the lowest priced responsible offeror.

The issue of affirmative purchasing and what most negative commenters characterized as the "mandatory use" provision of the proposed guideline, § 249.20(b), was by far the issue of most concern to commenters. At the public hearing, the Agency pointed out that § 249.20(b) is a "mandatory use" provision only if the individual procuring agency chooses to solicit bids only for cement or concrete containing fly ash, while excluding portland cement. This is not the same as the stricter approach which the Agency had considered taking in the proposal, which was to recommend that all agencies always require the use of cement or concrete containing fly ash, except where technically inappropriate.

Nevertheless, over half of the commenters considered the proposed § 249.20(b) as undesirable, arguing that cement and concrete containing fly ash should never be the only material specified, except in those very rare instances where it provides a property which portland cement alone cannot, such as low internal heat generation during construction of dams. Although EPA would have left this decision at the discretion of the procuring agencies, EPA now believes it is inappropriate to recommend it at all.

Despite the negative criticism of the "mandatory use" provision in the proposed guideline, a majority of commenters on this issue indicated support for an optional or alternate bid approach which allows for fly ash use.

EPA's recommendation in this final guideline is that procuring agencies specifically include provisions in individual contracts to allow for fly ash use as an optional or alternate material, unless the application is shown to be technically inappropriate. Award can then be made in accordance with normal and customary bid evaluation procedures, since these procedures (which generally require award to the lowest priced responsible offeror) tend to insure the purchase of cement or concrete containing fly ash only when it is reasonably priced (i.e., priced at or below the price of portland cement or concrete), reasonably available (i.e., offered by a responsible offeror) and technically appropriate. By notifying potential bidders that fly ash use is acceptable, the procuring agency thus essentially complies with its affirmative procurement obligation to purchase cement or concrete containing fly ash, except where not reasonably available, reasonably priced, or technically appropriate, since the natural operation of the bidding system tends to make this determination for the agency.

After reflection, EPA is convinced that the marketplace provides the best gauge of reasonable price, availability, and competition. It is inappropriate to artifically restrict the marketplace through limitation of bids, even where the procuring agency has independent knowledge that the cement or concrete containing fly ash is reasonably priced, available, etc. The reasons for this are discussed below.

Lack of Availability

Commenters claimed that the "mandatory use" proposal was inappropriate because quality controlled fly ash is not always available in every part of the country. As discussed previously, this is the "chicken and egg" dilemma for many recycled materials, i.e., is fly ash not available because there is no demand in those areas, or is there no demand in those areas because fly ash is unavailable? Supporters of fly ash use argue that if fly ash is more universally accepted, it will easily be more available.

Under the proposal, procuring agencies were required to restrict the bidding to fly ash where they knew it to be available. Nevertheless, the local unavailability situation does exist and procuring agencies can be mistaken in their assessment of reasonable availability. Agencies feel it is a waste of time and money to prepare and solicit bids solely for fly ash, only to find out there are no offerors. However, if fly ash is not the only product included in bid solicitations, availability will be determined by whether any bids are received for it, without the need for resolicitation. Allowing fly ash will also serve as an incentive to potential users in that area. Contractors will not make the commitment necessary to use fly ash unless it is more readily accepted. Including it in bid solicitations and allowing it to be used provides this incentive.

Cost Issues

The negative commenters almost always cited the potential for cost increases as a reason for never mandating sole use of fly ash. While the Agency did not propose to mandate sole use of fly ash, regardless of cost, it is true that use of certain classes of fly ash can cause a delay in early strength gains in contrete. This can lead to longer production times and *may* lead to cost increases. In addition, as noted in the proposed preamble, some equipment and technical expertise may have to be purchased in order to use fly ash successfully. Further, because of local unavailability, quality fly ash may only be available at a premium in certain areas.

If fly ash were required to be used, regardless of cost, some contractors would undoubtedly be left with no alternative but to raise their bid prices, without making the prices extraordinarily high or infeasible. However, if fly ash is merely allowed to be used but not required, portland cement concrete contractors will still be able to bid and award can be made to the lowest priced responsible bidder. Many fly ash concrete suppliers can economically compete, if given the chance to do so. If a builder can use fly ash in a cost effective manner, and guarantee performance and timeliness of the work, this is what the Government should be concerned with. An open bidding process successsfully addresses the negative commenters' contentions that cost increases are the inevitable result of fly ash use.

Technical Considerations

Many commenters voiced concern over technical problems which can arise when fly ash is used and which might be exacerbated under the "mandatory use" provision. These problems can often be attributed to use by inexperienced persons or use of low quality ash. However, there are legitimate technical concerns which do exist even when using high quality ash, for which mandatory use causes a dilemma—largely because the mandatory use provision requires the issue of technical appropriateness to be resolved at the outset, thus reducing flexibility.

One technical concern is the effect which climate can have. Use of fly ash can delay the curing time of concrete. Cold temperatures can compound this effect even further. Some manufacturers of blended cement containing fly ash recommend that their product should not be used at less than 50°F, except under close supervision. Flexibility to revert to portland cement concrete would be needed in such instances. On a long-term contract which spans the winter months, it is possible that fly ash concrete should most likely not be used. Serious contractual problems could arise if fly ash were specified as the mandatory material for that contract, and award made on that basis, while precluding portland cement suppliers. Procuring agencies would likely exclude fly ash altogether as an alternative, since it could not be used as the sole material for the entire contract.

One solution, however, is to allow that fly ash be used, at the option of the contractor, subject to approval of mix designs by the engineer. As materials change on a project, due to availability, cost, etc., new designs are often approved. In the case of fly ash, this flexibility should be permitted to the contractor.

Another technical problem is that fly ash may not be suitable for all uses within a project. A contractor bids on the entire project. Therefore, requiring a bid for either fly ash or not raises serious technical questions. Again, as an alternative, a procuring agency would likely exclude the use of fly ash altogether, since it could not be used for the entire project. However, with the more flexible approach EPA suggests in this guideline, the contractor and/or engineer can decide on which uses may not lend themselves to fly ash, on an item-by-item basis, *after* award of the contract.

Inexperienced Users and Ash Variability

Many commenters expressed concern that the so-called "mandatory use" provision might encourage use by inexperienced persons. As noted in the preamble to the proposed guideline, many contractors still lack knowledge of the proper use of fly ash in concrete and of the means of ensuring quality control. Commenters claim that if businesses are faced with the choice of either using fly ash or not bidding on a job, they will tend to use fly ash. EPA agrees that this could definitely lead to the use of low quality ash by unsophisticated users, or the failure to otherwise provide a satisfactory product. While ash from a single source may be of consistently high quality, a great deal of the fly ash generated is not suitable for use in concrete.

Although contractors are responsible for obtaining suitable materials and applying them properly, EPA believes that the problem of inexperienced users can best be avoided by employing an open bidding process in which bids for cement or concrete contining fly ash and portland cement or concrete are accepted. Furthermore, since fly ash does not currently enjoy widespread use, this solution will, in the long run, create greater acceptance by procuring agencies, engineers and contractors.

Restricts Use of Other Materials

Several commenters stated that the "mandatory use" provision, by restricting bids to the use of fly ash as a partial cement replacement in cement and concrete, would effectively preclude use of other recovered materials in cement and concrete. There are other waste materials, particularly blast furnace slag from iron production, which can be used successfully in cement production. Any suggestion on EPA's part that fly ash should always or even sometimes be the only material specified could be a major setback to development of other materials suitable for use in cement. It would be improper for EPA to create such barriers.

This problem can be overcome through allowing, not requiring, fly ash to be used. Contract specifications should be written incorporating references to both portland cement specifications and those for fly ash. As iron blast furnace slag is developed and becomes more readily available for this use, it should be included as a third optional material, at the discretion of procuring agencies. The American Society for Testing and Materials is actively working on development of such a standard for slag.

Competition Would Be Restricted

While adequate competition may exist (i.e., two or more bidders with reasonable prices) when soliciting bids only for fly ash, producers of portland cement concrete would be precluded from bidding. The primary purpose of the guideline is to work fly ash into the bidding system, because it is typically the excluded product at the current time. EPA would be reversing this situation with a mandatory fly ash use provision. We feel such an approach is unnecessary in the case of fly ash. With the approach that fly ash be included in the bidding system as an optional or alternate material, competition and business opportunities will increase, by allowing persons who are willing and able to use fly ash to bid on contracts on which they are now often precluded.

Bid Alternatives

Commenters have made EPA somewhat aware of the various methods which can be used to achieve the objectives expressed above. EPA discusses these methods in the guideline, and has left flexibility to procuring agencies in deciding which mechanism can best be implemented in their existing procurement system.

One approach is to allow for the use of fly ash through changes to contract or guide specifications, as discussed in this preamble in the section entitled "Specifications." Under this approach, the contractor would secure award of a contract based on normal bid evaluation procedures. At a later time, the contractor can exercise his option to use or not to use fly ash. Regardless of the choice made, normal quality assurance procedures apply, and review and approval of mix designs, materials, etc., must be performed by the project engineer. Some commenters characterized this method of solicitation as the "optional" approach.

A second purchasing method which some commenters suggested can be characterized as an "alternate bid" approach. Under this approach, a procuring agency would solicit bids requesting separate price quotations for either portland cement concrete or concrete containing fly ash. As in the case of the "optional" approach, award would be made in accordance with normal and customary evaluation procedures—typically to the lowest priced responsible bidder—regardless of whether fly ash is used.

The difference between this approach and the optional approach is that the contractor typically would be obligated to supply the material for which award is made for the duration of the contract, whether it be portland cement or fly ash. However, in order to accommodate situations in which fly ash may not be technically suitable for use in all phases of a project, or it becomes unavailable, EPA recommends that the winning contractor be allowed flexibility in amending his selection of materials planned for use, subject to approval of the procuring agency/project engineer, as long as he supplies at the agreed to bid price (or less).

EPA believes that the "alternate" approach holds most promise where the procuring agency is directly purchasing cement or concrete for a particular project, as where the U.S. Army Corps of Engineers purchases cement or concrete for a dam. In such a face-to-face bidding situation, where the procurement is strictly for cement or concrete, the procuring agency is in a position to directly evaluate the bids, make award, and evaluate requested material changes based upon the relevant factors.

The "optional" approach, on the other hand, holds most promise where the procuring agency is not directly purchasing cement or concrete, as in the situation where the procuring agency solicits bids for a construction project, such as a building, only one component of which is cement or concrete. In this situation, the price for cement or concrete is generally imbedded in the total bid price and the ultimate procurement of cement or concrete is by the contractor or the subcontractor, making evaluation of fly ash use in awarding the bid difficult or impossible. Indeed, commenters asserted that if the contractor bidding on the project had to commit to using fly ash or portland cement at the outset, the contractor would tend to specify portland cement, because fly ash may not be suitable for all construction applications on a given project. This, of course, would tend to retard fly ash use. Allowing the contractor to decide whether to use fly ash corrects this problem.

The "optional" approach should not be construed as a repudiation of the affirmative procurement requirements of Section 6002(c). Where cement or concrete is purchased ultimately by a contractor or subcontractor [illegible] by the Federal or state procuring agency, the contractor or subcontractor becomes a "procuring agency" for purposes of Section 6002 and the obligation to purchase fly ash is imposed on them as well. To insure that the contractor or subcontractor complies with this obligation, the guideline recommends that procuring agencies using the optional bid approach add a statement to their bid solicitations urging contractors and subcontractors to actively seek out suppliers of cement and concrete containing fly ash, and to solicit bids for these materials.

Regardless of the method of solicitation used, situations may occur where two or more low bids are received which offer different levels of fly ash content. While it generally would be desirable to make award to the bidder offering the highest fly ash content (assuming technical performance is maintained), there is a problem if that bid price is higher than that of other technically qualified suppliers.

The Agency considered establishing some type of "sliding scale" which would allow credits, and in effect additional payment for the supply of various ranges of fly ash in cement and concrete. This alternative was rejected because use of fly ash is cost competitive with portland cement use, rendering a price preference scheme unnecessary as a means of stimulating fly ash use.

The only so-called "preference" for fly ash which EPA has retained in this final guideline is in the case of identical low bids. In such instances award should be made to a contractor who plans to utilize the highest percentage of fly ash, all other factors being equal.

Recommendations as to Price, Competition, Availability, and Performance

Prices

Section 6002 raises the issue of "reasonable" price. Congress did not say that a recovered material product need cost less than or the same as the virgin material product it replaces, but merely that its cost be reasonable. Although a few commenters recommended that bonuses or premiums be paid to those persons using fly ash, the Agency rejected this idea for this guideline. Payment of premiums is generally unnecessary since the use of fly ash in cement and concrete is itself cost competitive. No price premium should be necessary to obtain cement or concrete containing fly ash. Indeed, to allow a premium on a regular basis may be unnecessarily inflationary.

This guideline leaves the determination of reasonable price to the discretion of the procuring agency, although the guideline does suggest general procedures for determining reasonable prices and price competition, based on procedures contained in the Federal Procurement Regulations applicable to certain types of procurements. The Agency cautions against determining reasonableness of price by comparing spot prices for relatively small quantities of cement or concrete containing fly ash with competitive bids for volume purchases of portland cement or concrete.

Competition

The primary purpose of competition is to secure the lowest price for a given product. Federal procurement procedures state that adequate competition is usually presumed to exist if: (i) At least two responsible offerors (ii) who can satisfy the Government's requirements (iii) independently compete for a contract to be awarded (iv) by submitting priced offers responsive to the expressed requirements of a solicitation. In addition, the prices should be examined for reasonableness.

Using the alternative bid approaches recommended by EPA, there should be no problem in achieving reasonable competition. Solicitation of bids for both portland cement or concrete and cement or concrete containing fly ash is recommended in all cases, thus enabling the procuring agency to better guarantee overall competition.

The existing Federal procurement procedures do not suggest comparing contracts with respect to numbers of bidders. They merely require that there be a sufficient number of bidders for adequate price competition for the particular contract at hand. EPA feels that as long as prices can be determined to be reasonable for cement and concrete which contain fly ash, then competition should be presumed to exist, no matter what the number of prospective offerors.

Availability and Delays

The Agency does not feel that procuring agencies should have to tolerate any unusual or unreasonable delays in obtaining cement or concrete which contain fly ash, other than delays which may be typically associated with portland cement and concrete. As specifications and purchasing practices are revised to allow for the use of fly ash, this material should become more widely available both geographically and in terms of the number of businesses willing and able to supply it.

Performance

The issue of reasonable performance is addressed in this preamble under the subsections on "Technically Proven Uses," "Specifications," and "Quality Control." Additional technical performance information is contained in the "References" section of this guideline.

In general, fly ash blended cement can be considered substitutable for all ASTM cement types except Type III, High Early Strength (and even these requirements can be met by adding, but not substituting, fly ash to a portland cement mixture). However, from a practical standpoint, the use of fly ash should be determined on a job-by-job basis, as there may be specific technical applications which would preclude the use of fly ash. As discussed in this preamble under "Contract Specifications," a procuring agency may document technical infeasibility for certain types of applications, rather than on a job-by-job basis. This practice should be considered acceptable as long as the purpose is not to circumvent the intent of RCRA.

The purpose of comparison to "reasonable" performance standards as required in Section 6002(c) of RCRA is to eliminate those standards, specifications, procedures, and practices

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which are overly restrictive and which unfairly discriminate, either directly or indirectly, against the use of fly ash. The use of reasonable performance standards is also intended to assure that the necessary technical performance requirements are still maintained, and that product quality is not reduced below acceptable limits.

Time-Phasing

Although the requirements of Section 6002 and the recommendations of this guideline should be implemented as quickly as possible, the Agency recognizes that problems could occur—in both the marketplace and governmental procurement systems—if implementation is pushed too rapidly. For example, the cost of fly ash suitable for use in cement and concrete could rise dramatically until the supply of suitable ash and storage capacity has a chance to increase. Construction contracts might include allowance for fly ash where it is technically inappropriate. Thus, this guideline recommends a phased-in approach to implementation.

The first year after the effective date of final publication of this guideline is reserved for specification review and revision. Beginning in the second year, procuring agencies should take affirmative action in their purchases of cement or concrete, using the recommendations of this guideline, in the manner discussed above.

A few commenters specifically supported EPA's recommended phasing-in approach. However, two commenters requested that delays be granted in implementing the guideline so that use of fly ash could be evaluated. In light of the discussions throughout this preamble regarding the technical and economic feasibility of using cement and concrete containing fly ash, EPA feels such delays would be unnecessary and counterproductive.

The Agency realizes that testing programs and the need for quality assurance are always necessary to assure the acquisition of acceptable materials. Such programs have been developed for fly ash.

Local and regional variations in the components of concrete always need to be taken into account when designing and approving concrete mixes, regardless of whether fly ash is used. EPA feels the one year implementation period is adequate for agencies to begin providing for fly ash use.

Another commenter suggested a two year implementation period, instead of one year, to allow voluntary consensus standards organizations an opportunity to react to guideline recommendations. EPA does not agree. Based on comments received from some of the major consensus standards organizations (ASTM, ACI), their standards often allow for fly ash to be used, subject to specific approval by the design engineer. However, if procuring agencies find revisions to consensus standards necessary, the guideline recommends that agencies reflect those revisions in their guide or material specifications, or on a contract-by-contract basis.

Certification

Section 6002 of RCRA requires vendors to certify that the percentage of fly ash to be included in the cement or concrete supplied under the contract is at least the amount required by applicable specifications or other contractual requirements. Further, vendors must estimate what this percentage is. This certification requirement is to take effect after a date to be specified in the guideline.

Some commenters objected to certification of fly ash content, stating it is a meaningless paperwork burden. Other commenters suggested use of simple certification clauses or procedures normally used by industry. EPA is leaving the exact certification language and format to the discretion of procuring agencies, but has provided suggestions here.

A simple certification clause is contained in the Code of Federal Regulations, 41 CFR Part 1–1, Subpart 1-1.2504, which states:

> The offeror/contractor certifies that recovered materials will be used as required by specifications referenced in the solicitation/contract.

The opinion of the Agency is that by signing the bid document/solicitation, the fly ash cement or concrete supplier is in effect agreeing to meet the fly ash content requirements. Thus, no separate form, signature, etc. is needed.

In addition to the inclusion of such a certification clause in solicitations, the supplier should certify the percentage of fly ash used. This should normally be done on a per project or per shipment basis, as opposed to certification of the average amount to be used over the course of a year, for instance. Except for technical performance purposes in concrete mix design, a procuring agency may allow the percentage to be certified within a small range, rather than requiring an exact percentage. The purpose of this flexibility is to not discourage potential suppliers who may be fearful that if an exact percentage is certified for a government contract, *only* that exact percentage may be supplied. Weather conditions or material variations, for example, may require modification of the concrete mix design and therefore the fly ash content.

This certification information is likely a necessity in evaluating concrete mix designs. However, procuring agencies can also use it in evaluating future contract requirements and in maintaining a record of fly ash use. Such information should be useful to procuring agencies in fulfilling their obligations under Section 6002(g) of RCRA, which requires agencies to submit annually a report to the Office of Federal Procurement Policy on actions taken by the agency to implement Section 6002.

Quality Control

The subject of quality control was of great concern to commenters. Some commenters misconstrued EPA's recommendations and thought that EPA was proposing to relieve suppliers of cement and concrete containing fly ash from many of the standard industry quality control and quality assurance procedures. These commenters apparently thought that EPA was replacing these standard procedures by the certification requirements discussed above. This is not the case. The certification procedures for fly ash content are entirely separate in purpose and format from quality control and quality assurance procedures.

EPA emphasizes that nothing in this certification section should be construed to relieve the contractor of responsibility for providing a satisfactory product. Cement and concrete suppliers are already responsible both for the quality of the ingredients of their product and for meeting appropriate performance requirements and will continue to be under this guideline.

Some commenters on the proposed guideline stated that EPA was incorrectly attempting to shift responsibilities and liabilities from fly ash suppliers to concrete producers and builders. EPA intends that no such shift take place. Responsibilities and liabilities are assumed to be in accordance with normal industry procedures.

Some commenters felt that fly ash should be subject to the same quality control/quality assurance provisions as for cement and other materials of construction. Many commenters felt that fly ash suppliers should be required to certify the physical and chemical characteristics of their material to users. EPA generally agrees with these commenters. Because the characteristics of fly ash can vary considerably between sources, knowledge of those characteristics is essential to assuring appropriate use of fly ash in cement and concrete. The Agency is recommending that fly ash suppliers be asked by users to provide a statement of the important characteristics of their fly ash. These characteristics are the chemistry of the material, loss on ignition (LOI), and fineness. Other characteristics should be requested as needed by the procuring agency. Further, EPA agrees with commenters who suggested that fly ash suppliers should be prepared to demonstrate the adequacy of their quality control programs, at least for new suppliers or those unfamiliar to the procuring agency.

The responsibility for insuring the quality of blended cement lies with the supplier. ASTM specification C595 specifies adequate requirements for quality control of fly ash used in blended hydraulic cements. Most blended cement manufacturers maintain quality control programs. No additional testing above that which would be required of any cement should be necessary on the part of the user/builder to insure compliance with this specification. However, the user must be conscious of any differences which may result in the field application of blended cement containing fly ash vs. portland cement.

The responsibility for insuring the quality of fly ash to be used as an admixture in concrete is that of the fly ash supplier. Although many suppliers of fly ash have their own quality control program, commenters pointed out that ASTM specification C618 may not be sufficiently stringent to ensure all ashes which comply are really suitable for general use as mineral admixtures in concrete, particularly when chemical admixtures such as air-entraining agents are to be used. Further, there is no assurance that all ashes which comply with specifications will be suitable for all uses. Thus, unfamiliar users must acquire the necessary technical expertise if they are to use fly ash successfully.

Some commenters suggested that States approve sources of fly ash. While EPA is not specifically recommending an "approved source" approach, the Agency does believe that fly ash and concrete suppliers should be expected to demonstrate (through reasonable testing programs or previous experience) the performance and reliability of their product. The judgement of the contractor/builder must be used in evaluating:

(1) Whether additional testing is necessary to insure the performance of the concrete, and

(2) Whether such testing is cost effective when compared with the cost of using other materials.

Fly ash which does not satisfy at least ASTM specifications should not be used in cement or concrete on Federal construction projects.

For those agencies desiring a testing or quality assurance program for cements, blended cements, or pozzolans, the U.S. Army Engineer Waterways Experiment Station (WES), P.O. Box 631, Vicksburg, Mississippi 39180, may be contacted. WES is the agency responsible for testing such materials for Federal agencies.

Date

EPA is charged with designating a time after publication of this guideline at which certification requirements will take effect. Certification of fly ash content should be a part of any solicitation which allows or requires the use of fly ash in cement or concrete. This guideline recommends a 12-month period after the effective date for review and revision of all guide and continuing contract specifications. After this 12-month period any solicitations/contracts issued should include provisions which allow that fly ash be supplied, and thus should incorporate certification requirements.

Compliance and Monitoring

EPA expects full cooperation from all Federal agencies in implementation of this guideline. The Office of Federal Procurement Policy (OFPP) has the major responsibility for overseeing implementation of Section 6002 of RCRA. The OFPP has indicated it will direct the Defense Acquisition Regulations and Federal Procurement Regulations overseeing bodies to immediately implement the final guideline.

The OFPP is responsible for monitoring and reporting annually to Congress on the actions taken by procuring agencies in implementing Section 6002 of RCRA. Under its Policy Letter 77-1, OFPP has imposed a reporting requirement upon the procuring agencies to gather this information. EPA, in conjunction with the OFPP, will monitor the impact of this particular guideline on the procurement practices of Federal agencies and on fly ash use. Thus, agencies are encouraged to develop procedures for gathering and maintaining such information.

A few commenters urged strict and active enforcement of the guideline by EPA. Among the specific suggestions were debarment of contractors for major certification violations, provision by EPA of technical assistance to States and other agencies in the revision of specifications and the use of fly ash, and monitoring by EPA of its own contractors and grantees.

EPA expects a high level of compliance with the guideline. If necessary, the Agency is prepared to take appropriate measures to ensure that the objectives of the guideline are met. In addition, there are other methods available to interested parties to encourage compliance with Section 6002. One of these methods is the citizen suit provision of Section 7002 of RCRA, which states:

> (a) * * * any person may commence a civil action on his own behalf—(1) against any person (including (a) the United States, and (b) any other governmental instrumentality or agency * * *) who is alleged to be in violation of any permit, standard, regulation, condition, requirement, or order which has become effective pursuant to this Act.

A second method which may be useful in encouraging compliance with Section 6002 is the filing of formal protests by aggrieved bidders. A bidder who is willing and able to supply a "designated" recovered material product to procuring agencies and who is precluded from bidding by failure of a procuring agency to comply with Section 6002, may be able to obtain satisfaction through this process.

Regulatory Analysis

In this and other sections, the preamble contains discussions of the elements required in a Regulatory Analysis: (1) The program objectives, (2) our consideration of regulatory alternatives, (3) a general assessment of our choices, (4) a description of potential benefits and costs and (5) the rationale for our decisions. EPA believes it is complying with the intent of Executive Order 12291 because of this and other efforts, including the preparation of a more detailed background document to support the analyses below. This document may be examined at the RCRA Public Docket Office, at the place and times listed previously in this preamble.

Effects

(1) *Economic savings.* This guideline should help the cement industry by reducing both energy costs and capital investment requirements for capacity expansions. Adding effective capacity by using fly ash to produce blended cement is a viable alternative to new kiln construction. Adding capacity with fly ash involves about ten percent of the

capital cost of a new plant ($5–$15 per ton added capacity using fly ash vs. $125–$185 per ton for a new cement plant).

The purchased energy cost associated with cement production represents one-third of the finished value of the cement—very high in relation to other building materials. At a typical blending rate of 20 percent, fly ash in cement can reduce total energy use about 15 percent. The portion of total cost represented by this energy savings—currently five percent—will grow as the cost of purchased energy increases.

For cement consumers, i.e. ready mixed concrete producers, concrete product manufacturers, and highway contractors, fly ash can reduce raw material costs. Cement prices range from $40–$90 per ton, while the price of fly ash suitable for use in concrete may range from about $15–$50 per ton. Depending on the replacement rate and relative price of the two materials, substituting fly ash can save 5 to 15 percent of the cost.

Procuring agencies may not be in a position to realize the savings described here with respect to their purchases of blended cements. Because of the pricing structure and concentrated nature of the cement industry, and the fact that properly blended cement containing fly ash may perform as well or better than portland cement—blended cements containing fly ash (ASTM Types IP and I(PM)) are likely to be priced at the same level as ASTM Type I portland cement. However, concrete producers are able to take direct advantage of decreased raw materials cost by purchasing fly ash as a partial cement replacement. Given the greater competition among the large number of firms in these industries, bid quotations for concrete may reflect part of these savings.

(2) *Energy Conservation.* In 1978, the portland cement industry accounted for two percent of total energy used by U.S. industry. Although the cement industry has steadily reduced its energy consumption per unit of product over the past several years, the use of fly ash in producing blended cements can still save a significant amount of energy.

Seventy to eighty percent of the energy used in cement production is consumed during the pyroprocessing stage, where raw materials are subjected to intense heat and chemically react to form cementitious compounds, or clinker. The clinker is ground into the fine powder known as cement. Replacing the cement clinker with fly ash (on a one-to-one ratio by weight) reduces the amount of clinker production required per ton of finished cement. Energy savings are proportioned to the percentage of fly ash used in the blend. Assuming a 20-percent replacement rate, the savings may range from about 13 to 19 percent of total energy used in production.

Concrete producers can save energy indirectly, on a nationalized basis, if fly ash is used as an admixture at their plant. Replacing a portion of cement with fly ash in the final product would reduce the production needed from the cement industry, and thus would reduce energy consumption. Each ton of cement replaced would save approximately 5,750,000 BTU's of energy.

One commenter pointed out that the energy savings presented here are not totally achievable for new cement plants which have been designed to take advantage of energy conserving technologies. While this statement is true when considering BTU's, the percentage energy savings are nevertheless achievable by bypassing the pyroprocessing stage, regardless of the efficiency of the plant involved.

Another commenter claimed that increased energy consumption would take place in the precast and prestressed concrete industry, due to the higher temperatures needed to achieve equivalent early strengths when using fly ash. Since the use of fly ash is considered to be at the manufacturer's option under this guideline, EPA feels that if increased energy consumption is prohibitive for precast and prestressed manufacturers, concrete containing fly ash will not be utilized.

(3) *Environmental Issues.* (a) *Benefits.* The use of fly ash in cement and concrete will have a positive effect on the environment, reducing pollution of the land, air, and water. It will do this by reducing: (1) The quantities of fly ash requiring disposal, (2) the mining and processing of raw materials used in cement production, and (3) the cement plant emissions per ton of blended cement produced or per ton of cement replaced with fly ash.

If current usage rates continue, by 1985 60–65 million tons of fly ash annually will require disposal. Approximately 10–20 million tons of this fly ash are estimated to be suitable for use in concrete. This guideline can affect the practices of collecting fly ash, especially from new sources, and can reduce the quantities which require ultimate disposal. Thus, the use of fly ash in cement and concrete will provide a more environmentally acceptable way to manage these substances than would otherwise be available.

Current practices for cement manufacturing, and current disposal practices for fly ash, can have a negative effect on air quality (increased dust), water quality (surface and groundwater contamination), land use, noise, and aesthetic value. The use of fly ash in cement and concrete can reduce these effects in several ways. For example, it would reduce the need for such raw materials as limestone and clay, whose mining and processing can harm the environment through the creation of increased dust, erosion, runoff, and noise, disturbance of natural habitats, and degradation of potential land use. Use of fly ash reduces the potential for leaching of trace heavy metals, which could occur as a result of indiscriminate fly ash disposal.

Requiring less cement for the same quantity of "cementitious" end product may reduce the amount of cement kiln dust which requires disposal (currently 6–8 million tons per year). The disposal of cement kiln dust can have the same harmful effects (i.e., air quality, water quality, land use, aesthetic value, etc.) as the disposal practices of fly ash. In addition, using fly ash to increase the capacity of a cement plant would most likely reduce the need for air pollution control since it would not require the air pollution control associated with new kiln construction. This approach to expanding capacity may be especially attractive in "nonattainment" areas, where new kiln construction is effectively precluded.

(b) *Impact of RCRA, Subtitle C.* In May 1980, EPA promulgated regulations for the control of hazardous waste pursuant to Subtitle C of RCRA. In the Solid Waste Disposal Act Amendments of 1980, Congress directed EPA not to regulate fly ash as a hazardous waste until such time as EPA investigates the environmental hazards, if any, posed by fly ash disposal. Findings to date indicate that little, if any, fly ash exhibits characteristics defined as hazardous in the Federal regulations. Therefore, Subtitle C regulations will have no significant impact on the use of fly ash in cement and concrete.

A few commenters suggested that EPA limit the use of fly ash in concrete, restricting its use in potable water sources or in storage areas for food. The rationale given for these suggestions was the potential for leaching of trace metal elements out of the fly ash. The commenters provided no documentation as to the likelihood or extent of leaching when fly ash is used in concrete.

While it is true that fly ash contains trace amounts of certain elements, which can be toxic in larger concentrations, it is unlikely that fly ash as used in concrete would exhibit leaching characteristics. First, the premeability of concrete containing fly

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ash is negligible compared to the permeability of fly ash as typically exposed. This reduced permeability prevents water or other liquids from penetrating concrete and providing a leaching medium through which contaminants could travel.

Second, when used in concrete, fly ash becomes an integral part of the final product. The surface area of individual fly ash particles, from which leaching of trace constituents takes place, is so greatly reduced in this application as to be almost nonexistent. It is not possible through conducting leaching tests of raw fly ash to estimate the leaching, if any, which would take place in a concrete containing fly ash. Thus, the commenter's suggestion that dams and pipes not be constructed using fly ash appears to have no technical basis.

(c) *Radioactivity Issues.* At the same time as original proposal of the hazardous waste regulations (December 18, 1978), EPA issued an advance notice of proposed rulemaking that it was considering establishing 5 picocuries per gram (pCi/g) of radium-226 as a criterion for listing wastes as hazardous. The notice also requested comment on other criteria which might tend to affect the radiation [illegible] emanation rate of radon from the waste. The Agency has, at this date, taken no further action on this proposed rulemaking to establish general criteria for hazardous radioactivity levels in wastes.

Where resource recovery is practiced, an important consideration in assessing the hazard is the proposed use of the waste material. While some proportion of fly ash generated in the U.S. has more than 5 pCi/g of radium-226, the physical structure of fly ash is such that its contribution to radiation exposure is probably less than that of most normal constituents of concrete which generally fall below this level. This is explained below.

A few commenters expressed concern to EPA that fly ash used in the construction of habitable structures could pose a threat to public health due to radioactivity. The source of the radiation threat is due to radium-226, a radioactive isotope which occurs naturally in soil, sand, and mineral deposits as well as in fly ash. The radium-226 content of soil generally ranges from .2 to 3 pCi/g. Limited measurements of radioactivity in cement show that the radium-226 content of cement can be as high as 5 pCi/g, but typically averages close to 1 pCi/g. Limited measurements of fly ash presently generated in the U.S. show a radium-226 content ranging from 1 to 8 pCi/g with an average of roughly 4 pCi/g.

There are two pathways of radiation exposure from radium-226 in building materials. The pathway of primary concern is from inhalation of radon-222 and its short-lived decay products. Radon-222, an inert gas with a radioactive half-life of 3.8 days, is the first generation decay product of radium-226. Because it is an inert gas, it can readily migrate from the building material into the indoor air of a home. Although the rate at which radon is created within a building material is proportional to its radium content, the intrinsic structure of the material may, in some cases, prevent most of the radon from escaping. When air containing radon and its radioactive decay products is breathed for long periods of time, a person's risk of lung cancer is increased.

Gamma radiation from radium-226 and its decay products is the other exposure pathway. The amount of gamma radiation emission from a building material is proportional to its radium content, but the total exposure a person receives will also depend on other factors such as shielding, distance from the material, and exposure time. Exposure to gamma radiation results in an increased risk of many types of cancer.

When fly ash is used as a partial cement replacement in concrete, the fly ash content of the final concrete product is between 2 and 3 percent (assuming a 15 to 25 percent cement replacement rate and an 8 to 1 ratio of aggregate and water to cementitious material). Since the average radium-226 content of fly ash exceeds that of cement by a few pCi/g, the use of fly ash as a cement replacement in habitable structures will, on the average, result in a slight increase in the gamma radiation exposure to people (less than a milliroentgen per year). However, in some instances, where fly ash with a lower than average radium content replaces a cement with a higher than average radium content, the result would be less gamma radiation exposure.

The use of fly ash as a cement replacement will also affect the quantity of radon emitted by the building material. Although the rate at which radon is created is directly proportional to the radium content, other factors may inhibit radon emanation from a material. Because fly ash is produced at high temperatures, it has a glassy structure which keeps most of the radon from escaping. The fraction of radon which escapes from fly ash (emanation fraction) has been measured at no more than a few percent. In contrast, typical soil and soil like materials tend to have an emanation fraction in the neighborhood of 20 percent. Thus, although fly ash, on the average, has a greater radium content than the cement it replaces, the use of fly ash as a partial cement replacement is likely to reduce the radon gas contribution of the final concrete product.

During the proposal period for this guideline, EPA has been investigating this issue more thoroughly. Tests recently conducted for EPA substantiate the conclusions above, i.e., that the radon emanation rate of fly ash in its raw state and as used in concrete is only a few percent compared to the absolute radium concentration. Thus, while fly ash use in cement would, on the average, result in a small increase in gamma radiation exposure, this small increase in gamma exposure is likely to be offset by a decreased radon exposure. In light of this, EPA believes that the use of typically-occurring fly ash in concrete does not constitute a significantly different radiation risk than the risk from the cement it replaces, and neither of these is significantly different from the radiation risk posed by [illegible] common soil.

Institutional Issues

In spite of proven technical performance and favorable economics, the use of fly ash in cement and concrete has had only limited acceptance. This can be attributed in part to potential consumers' unfamiliarity with fly ash, and their reluctance to aggressively investigate or readily accept new materials where an existing product—in this case portland cement—has traditionally been accepted. In some cases there may be outright discrimination against this use of fly ash, because of attitudes, personalities of individuals involved, and political and economic pressures. Several commenters stated that this Federal procurement guideline is necessary to overcome the lethargy of specifying engineers, inertia of the construction industry, unfair competition from vested interests, and resistance to use by some factions of State highway departments and the Federal Highway Administration.

It is difficult to obtain quick approval for a new product or material specification in the construction field, given the requirements for experimentation, demonstration, field evaluation and finally specifications changes. However, it should be recognized that fly ash has already gone through these steps. There are established specifications and standards for the testing and use of this material. Sources of ash must be acceptable and EPA emphasizes that only ash which meets established specifications should be used. However, a procuring agency need not "reinvent the wheel" by requiring extensive and expensive reevaluation of the basic feasibility which has already been proven. This applies to all government agencies, but especially to state and local entities, which use such instruments as building codes to regulate construction activities.

Design engineers generally have the final say on the materials to be specified for a particular construction job. Typically, until a majority of peer engineers accept a "new" material there is reluctance to use it. However, an engineer can meet his or her responsibility for the performance of a structure by conducting a thorough review of the concrete mix design before placing the concrete, and assure that the materials and mix design meet, as a minimum, ASTM, Federal, and/or American Concrete Institute specifications. The intent of this guideline is to help overcome certain of these "institutional" barriers which may have no adequate foundation, while maintaining satisfactory product quality.

Resource Requirements

The cost to procuring agencies of compliance with this guideline will be minimal. The price of cement and concrete containing fly ash should be less than or equal to the price of portland cement and concrete. The start-up costs of revising specifications and assimilating fly ash into the procurement system should be relatively minor but are not readily measurable.

The Office of Federal Procurement Policy (OFPP) is responsible for submitting an annual report to Congress on actions taken by Federal agencies and the progress made in implementation of the resource recovery policy of Section 6002. As a result, OFPP already requires an annual report from each Federal agency on actions taken in the implementation of Section 6002. By working closely with OFPP, information relevant to the implementation of this guideline can be obtained. The costs to OFPP and EPA of implementing this guideline are expected to be relatively minor.

EPA's efforts during the first year following promulgation of the final guideline will focus on explaining the guideline provisions to interested persons and responding to inquiries regarding implementation of the guideline. The Agency urges individuals with an interest in seeing the guideline implemented to deal directly with those persons responsible for compliance with Section 6002, i.e., procuring agencies, and ultimately with architects, engineers, etc.

Public Participation

Prior to proposal, an interagency work group, including representatives from most of the Federal agencies which will be directly affected by this guideline, assisted in development of the proposed guideline. In addition, a draft of the proposed guideline package, including a summary development plan, preamble, rule, and background documents was circulated to well over 200 interested persons for comment. Public participation regarding formal proposal and comments on the proposed guideline was presented at the beginning of the section of this preamble entitled "SUPPLEMENTARY INFORMATION."

Compliance With Executive Order

Under Executive Order 12291, EPA must judge whether a regulation is "Major" and therefore subject to the requirement of a Regulatory Impact Analysis. This guideline is not major because it is not likely to result in:

(1) An annual effect on the economy of $100 million or more;

(2) A major increase in costs or prices for consumers, individual industries, Federal, State, or local government agencies, or geographic regions; or

(3) Significant adverse effects on competition, employment, investment, productivity, innovation, or on the ability of United States-based enterprises to compete with foreign-based enterprises in domestic or export markets.

This guideline recommends that procuring agencies include provisions in construction contracts which specifically allow for fly ash to be used, with the contractor retaining the option to use fly ash. Typically, fly ash is currently precluded from use on construction projects unless it is specifically called for in the contract specifications. As discussed in other sections of the preamble, particularly "Regulatory Analysis," this guideline should not adversely affect competition. With the approach that fly ash be allowed into the bidding system as an alternate material, competition and business opportunities are increased by allowing persons who are willing and able to use fly ash to bid on contracts, while still allowing suppliers of conventional portland cement and concrete to compete.

With regard to costs, this guideline should help the cement industry by reducing both energy costs and capital investment requirements for capacity expansions, through the blending of fly ash with cement. For cement consumers, i.e., ready-mixed concrete producers, concrete product manufacturers, and highway contractors, use of fly ash can reduce raw material costs, as fly ash is generally priced less than the cement it replaces, although savings will vary. On a micro-scale, however, individual companies may be placed in the position of losing bids to competitors who choose to use fly ash, and who bid lower.

EPA has prepared a detailed background document supporting the above analysis. This document may be examined at the RCRA Public Docket Office, at the place and times listed above.

This guideline was submitted to the Office of Management and Budget (OMB) for review as required by Executive Order 12291.

Dated: January 21, 1983.

Anne M. Gorsuch,

Administrator.

List of Subjects in 40 CFR Part 249

Resource recovery, Recycling, Fly ash, Procurement.

Title 40 CFR is amended by adding a new Part 249 reading as follows:

PART 249—GUIDELINE FOR FEDERAL PROCUREMENT OF CEMENT AND CONCRETE CONTAINING FLY ASH

Subpart A—Purpose, Applicability, and Definitions

Sec.
249.01 Purpose.
249.02 Designation.
249.03 Applicability.
249.04 Definitions.

Subpart B—Specifications

249.10 Recommendations for guide specifications.
249.11 Recommendations for contract specifications.
249.12 Recommendations for material specifications.
249.13 Recommendations for fly ash content and mix design.
249.14 Recommendations for performance standards.

Subpart C—Purchasing

249.20 Recommendations for bidding approach.
249.21 Recommendations for reasonable price.
249.22 Recommendations for reasonable competition.
249.23 Reasonable availability.
249.24 Recommendations for time-phasing.

Assessment of Potential Public Health Impacts Associated with Predicted Emissions of Polychlorinated Dibenzo-Dioxins and Polychlorinated Dibenzo-Furans from the Brooklyn Navy Yard Resource Recovery Facility

Prepared for:

New York City Department of Sanitation

Prepared by:

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August 17, 1984

Appendix 10.16

Assessment of Potential Public Health Impacts Associated with Predicted Emissions of Polychlorinated Dibenzo-Dioxins and Polychlorinated Dibenzo-Furans from the Brooklyn Navy Yard Resource Recovery Facility

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Executive Summary

A. Introduction

The purpose of this report is to assess the potential health risks associated with the emission of polychlorinated dioxins (PCDDs) and polychlorinated furans (PCDFs) from the proposed Brooklyn Navy Yard Resource Recovery Facility (BNYRRF). This document was prepared at the request of the New York City Board of Estimate.

A panel of nine technical experts was assembled to provide guidance in the preparation of this report and to review and comment on its approach and conclusions. This review panel is composed of local, national, and international authorities in both scientific and regulatory areas of dioxin research. Meetings were held with the panel on February 28th to review the scope of this study, and on April 29th, 1984 to receive comments on a preliminary draft, prior to review of the final document in July. These comments, and the panel's evaluation of the report's technical and scientific merit appear as an appendix to the report.

The information contained in this document was gathered through an extensive review of the available literature on the properties of dioxins and their emission from resource recovery facilities. Where appropriate, this data was supplemented by conversations with technical and regulatory authorities. This report is not, and was not intended to be, a product of original research.

B. Approach

In order to assess the potential risks associated with the predicted BNYRRF emissions, the report was divided into five separate work elements: (1) a review of the literature on the chemical, physical, and toxicological properties of PCDDs and PCDFs; (2) an analysis of available data pertaining to the high-temperature behavior of PCDF and PCDD and the prediction of PCDD and PCDF emission rates for the proposed BNYRRF; (3) a detailed modeling program to predict maximum annual downwind concentrations of PCDFs and PCDDs in the ambient air, soil, dust and dirt; (4) a risk assessment which compared the concentrations of contaminants known or predicted to cause a toxic effect to the predicted level of exposure of local populations; (5) an evaluation of the upper limit excess cancer risk predicted by the risk assessment in the context of comparative risks.

In addition, this report contains the following appendices:

(A) a compilation of published PCDD and PCDF emission data;

(B) example calculations to show how quantitative results were derived;

(C) a discussion of certain issues related to facility operations; an evaluation of the impact of operating and emissions controls on PCDD and PCDF emissions; an evaluation of potential occupational and public health risks associated with fly ash disposal; recommendations for facility operations;

(D) the written comments of the peer review panel members on the final draft of this report;

(E) the curriculum vitae of the peer panel members;

(F) a statement of the qualifications and experience of Fred C. Hart Associates.

C. Findings

C.1 Properties of Dioxins

Data on the toxicity, persistence, bioavailability, and transport characteristics of PCDDs and PCDFs was reviewed to provide background information necessary to conduct a risk assessment of dioxin emissions from the BNYRRF.

"Dioxin" is a generic term for a family of compounds known as polychlorinated dibenzo-p-dioxins (PCDDs). Altogether, there are a total of 75 different PCDDs which can vary in the number of attached chlorine atoms and the positions of attachment. There are eight possible locations for chlorine atoms on dibenzo-p-dioxin. "Furans" are a family of 135 similar chlorinated compounds, the polychlorinated dibenzofurans (PCDFs), differing chemically from dioxin in that the two constituent benzene rings are linked by one, rather than two, oxygen atoms.

Congeners of dioxin differ from one another by the number of attached chlorine atoms. Those compounds with four chlorine atoms are known as "tetra-chlorinated" dioxins or furans (TCDD and TCDFs or T_4CDDs and T_4CDFs), those with six chlorine atoms are known as "hexas" (HCDDs and HCDFs or H_6CDDs or H_6CDFs), etc. Isomers of dioxins have the same number of chlorine atoms but vary in their position of attachment.

PCDDs and PCDFs are present in the environment from several sources. Dioxins have been produced largely as unwanted contaminants from the manufacture of trichlorophenols, herbicides such as 2,4,5-T, and chlorobenzenes and polychlorinated biphenyls. In addition, both chlorinated dioxins and furans are associated with a variety of combustion sources.

Little is known about the actual fate of dioxins in the environment. Most of the available data, which is often conflicting, is for the 2,3,7,8-TCDD isomer. The properties of the other isomers frequently are inferred based upon structural/functional similarities with 2,3,7,8-TCDD and other highly chlorinated aromatic hydrocarbon species. It is known that all PCDDs and PCDFs are resistant to chemical, physical, and biological degradation and thus are very stable in the environment. They have a strong affinity for binding to organic substrates, such as soil and sediment, and to fly ash. Due to their low water solublility and high binding affinity for soils, they do not migrate substantially in soils.

Volatilization from soils through vapor phase transport is dependent on ambient temperature and is thought to be a major removal pathway. The primary removal mechanism of dioxin from water is through adsorption by sediment or biota, although volatilization and photodegradation may occur to some extent.

Polychlorinated dioxins in the atmosphere are present in the particulate-sorbed or vapor phase. They may be removed from the air by atmospheric deposition or photochemical degradation. The environmental half-life has been reported to range from one-half year up to twelve years.

Animal studies, which are limited primarily to testing 2,3,7,8-TCDD, indicate that this compound shows considerable variation in toxicity among different species, as well as a delay between administration and the manifestation of a toxic effect. The acute toxicity of different PCDDs varies widely (e.g., in guinea pigs by six orders of magnitude), depending on the number and the location of the chlorine atoms.

Relatively little is known about the effects of PCDDs and PCDFs on humans. Most information on human health effects is derived from cases of accidental exposure to chemical mixtures containing PCDDs and other compounds. Correlating the effects of these uncontrolled exposures to exposure to PCDDs is difficult. The symptom most frequently associated with exposure to PCDDs (and some related chlorinated hydrocarbons) is chloracne, a skin condition.

2,3,7,8-TCDD has been proven carcinogenic in several animal models. Although there is some indication of a relationship between human exposure to phenoxy herbicides (contaminated with trace levels of dioxins) and the development of certain cancers, notably soft-tissue sarcomas, most data are inconclusive. In general, evidence for human carcinogenic effects is not as substantive as that for animal models. At this time, it is not clear whether PCDDs act as promoters or initiators of carcinogenesis. (An "initiator" of carcinogenesis is a substance which directly induces cancer; a "promoter" is a substance which, by itself, does not directly induce cancer, but which, in combination with known carcinogens, may increase the probability that cancers will be induced. While most initiators of carcinogenesis are considered to pose some cancer risk at any level--no matter how small the dose--many promoters are thought not to have a deleterious effect at levels below a certain threshold dosage.)

Teratogenesis and other reproductive effects have been noted in mice and rats. However, studies of human populations conducted to date have not shown a significant increased risk of spontaneous abortions and birth defects for populations exposed to PCDDs.

Available data on the mutagenicity of 2,3,7,8-TCDD seem to indicate that this compound is not mutagenic in the test systems used. Chromosomal analysis of plant workers exposed in an industrial accident at Seveso, Italy, did not reveal statistically significant increases in chromosome damage.

C.2 Dioxin Emissions From Incineration

An extensive examination of literature focusing on the high temperature behavior of dioxins in incinerators was conducted. Reports of laboratory studies as well as sampling and analysis data on flue gases from actual full-scale incinerators were included.

The literature indicates that PCDF and PCDD emissions in incinerator effluents can originate from a number of sources and/or chemical reactions, such as being a part of raw refuse, being formed from precursors, and being formed from degradation products of materials commonly found in solid waste.

It is unlikely that trace amounts of dioxin present in the raw refuse are the source of dioxin emissions from municipal solid waste combustion. Although some dioxin emissions may originate with the raw refuse, it is more likely that precursor compounds in the refuse become chlorinated during the combustion process to form dioxin.

There have been investigations, therefore, of ways to control dioxin formation by separating either the oxygen-benzene-type precursor compounds to which chlorine may become attached, and/or by separating the chlorine sources such as polyvinyl chloride (PVC) from the raw waste stream. Both laboratory data and field measurements of existing incinerators and combustion processes, however, indicate that pre-separation of specific refuse types from the waste stream before combustion is not likely to have an appreciable affect on dioxin levels. One investigator, for instance, spiked waste burned in a waterwall incinerator with three times the normal amount of PVC and found no significant difference in dioxin levels.

Dioxin levels do seem to be affected, however, by a series of combustion conditions which can be controlled and monitored in modern resource-recovery incinerators. The combustion conditions necessary for destruction of PCDDs and PCDFs include a minimum of one to two seconds of gas residence time at a combustion temperature of 900-1,000°C, very turbulent conditions in the high-temperature zone, and an air/fuel mixture with a slight excess of oxygen.

The incinerator design selected for the BNYRRF appears to fulfill the requirements for efficient combustion and maximum destruction of PCDFs and

PCDDs. Furthermore, the planned use of auxiliary burners will help assure that the minimum combustion temperature is consistently maintained. Continuous monitoring of temperature, oxygen and carbon monoxide levels will allow combustion conditions to be maintained within specific parameters, as long as operators response is effective and immediate to deviations from the optimum levels.

The BNYRRF will utilize a more efficient fly ash pollution control device than is generally used on incinerators. Since at least some of the PCDF and PCDD materials will be adsorbed on particulates, less of these materials will be emitted than if the less efficient electrostatic precipitator had been selected.

Of the available technologies, the system design for the BNYRRF appears to minimize potential PCDF and PCDD emissions to the greatest extent feasible. While it is possible that the addition of a dry scrubber (acid-gas-control) technology in combination with the fabric-filter air pollution control device might further limit these emissions, there is not sufficient data currently available to allow an accurate prediction of the actual effectiveness of this relatively costly alternative.

Emission test data from a number of incinerators has demonstrated a wide range of PCDF and PCDD emissions spanning several orders of magnitude. However, the lowest emissions were observed from incinerators with the same basic design as the BNYRRF.

Actual emission data from operating municipal resource recovery facilities were used to predict PCDD and PCDF emission rates from the BNYRRF. In selecting the test data, the objective was to utilize data from facilities similar in design, operations, and waste types to the BNYRRF. Furthermore, the test data had to be obtained using sampling methods that are compatible with methods approved by USEPA for sampling organics in flue gases under rigorous quality control procedures.

The emission data selected as the most representative of the BNYRRF are the data from the Chicago Northwest facility and the Zurich-Josefstrasse facility. Both of these facilities use a furnace design similar to that proposed for the BNYRRF. The sampling of the Chicago Northwest facility was performed under sponsorship of the USEPA, using approved methods and quality assurance protocols in order to assure representativeness. The Zurich-Josefstrasse facility was tested by the Swiss counterpart to the USEPA. However, both of these facilities utilize electrostatic precipitators for fly ash control, while a fabric filter has been proposed for the BNYRRF.

Because there are no appropriate dioxin emission data available for incinerators with fabric filters, two emission scenarios had to be developed in order to model the BNYRRF emissions: (1) based on the assumption that all PCDF and PCDD materials observed in previous tests were gaseous in nature and pass through the fabric filter without collection, and (2) based on the assumption that all PCDF and PCDD materials observed in previous tests were adsorbed onto fly ash, part of which was subsequently assumed to be trapped in the fabric filter. The second case is believed to be the more likely alternative. The actual emissions from the BNYRRF could fall between these values, depending upon the portion that is gaseous and the portion that is particulate-bound. Both cases are examined in the risk assessment.

Since there is consensus in the literature that, where PCDDs and PCDFs are adsorbed on fly ash, the concentrations are higher on the smallest particles, and the adsorption is a particle surface phenomenon, it was assumed that PCDF/PCDD concentrations on particles were proportional to the surface area available for a given particle size. Test data from incinerators with electrostatic precipitators were used to derive a concentration distribution by particle size. This distribution was then used with particle size data from a unit with a fabric filter to calculate the amount of particle entrapment and, therefore, the amount of PCDF/PCDD entrapment in a fabric filter over and above that which would be trapped in a comparable electrostatic precipitator. This formed the basis for the predicted emission rates under the scenario where all PCDFs and PCDDs are particulate-bound.

C.3 Exposure Assessment for Emissions from the Proposed BNYRRF

Impacts of PCDD and PCDF emissions from the BNYRRF can be manifested in two ways: (1) as above background concentrations of PCDDs and PCDFs in ambient air; and (2) as deposition of PCDD and PCDF particulate emissions on horizontal surfaces.

To assess the impact of the proposed BNYRRF on the general population, the ambient air concentrations were evaluated at a large number of ground-level and evaluated receptors using the MPTER-Urban computer dispersion model. The PCDD/PCDF deposition rates at a large number of ground-level receptors were calculated using the deposition option of the ISC computer dispersion model. The deposition rates were used to calculate maximum annual downwind dioxin concentrations in soil, street dirt, and house dust. The following assumptions were made based on the best available data and modeling techniques:

- Available studies do not show definitively the amount of isomer transformation, or biological, chemical, or photolytic degradation of PCDFs and PCDDs in the atmosphere. Therefore, the conservative approach of assuming no isomer transformation or degradation was taken to compute both dispersion concentrations in air and deposition rates on the surface.

- Although it is known that particle size, shape, and weight may change during transport from source to receptor, there are no methods available to compute these physical particle changes. The deposition analysis assumes that particles do not change in size and weight, and the dispersion analysis assumes that all particles are so small that they are transported in the same way as a gas molecule would be transported.

- The deposition analysis method does not consider the aerodynamic influences of elevated terrain, buildings, or resuspension and re-entrainment of particles. Since this is the best method available at this time to compute deposition rates from a point source, there has been no attempt to change this method of analysis.

C.4 Risk Assessment

A risk assessment was performed to estimate the risks associated with predicted maximum PCDD and PCDF concentrations in ambient air, soil, dust and dirt downwind of the BNYRRF. The assessment compared the predicted ambient air concentrations and estimated daily intake levels for PCDDs and PCDFs with: (1) applicable standards and criteria; and (2) concentrations of PCDDs and PCDFs known or suspected to cause a toxic effect.

In reviewing the findings of our risk assessment it is important to keep in mind the methodological limitations of the risk assessment process.

First, a risk assessment, while based upon scientific considerations, often requires the application of sound technical and scientific judgement or assumptions. The use of assumptions rather than scientific data is often necessary because frequently there is an inadequate data base on the environmental fate, transport, and bioavailability of contaminants such as PCDDs and PCDFs.

Second, a risk assessment frequently requires extrapolation from high-dose animal feeding studies to estimate risk to humans at the extremely low dosages or concentrations of contaminants found in the environment. Data are not available to determine the actual shape of a dose/response curve (i.e., the level of risk), or the best method to extrapolate risk. Accordingly, there is a great range of uncertainty regarding actual risk (at very small concentrations) for a given contaminant.

In the absence of sufficient data or knowledge about the degree of exposure, intake, and bioavailability of contaminants, the typical risk assessment uses the most reasonable assumptions possible. Typically, "worst-case" scenarios or conservative assumptions are used in the assessment process. A conservative assumption is one which increases the likelihood that a substance will represent a hazard to public health.

However, the use of a number of "worst-case" or conservative assumptions carries the danger that the estimate of risk can become vastly overstated and therefore unrealistic. Risk assessments relying upon "worst-case" scenarios must be evaluated critically regarding the degree of realism in the model used to estimate risk.

Several conservative assumptions were incorporated into our assessment. They include the following:

- Use of worst-case assumptions for three potential pathways of exposure: inhalation of gaseous or particulate emissions, and ingestion or dermal absorption of particulates deposited on outdoor and indoor surfaces. Typically, risk assessments of point-source emissions assess risks only for the inhalation pathway.

- Application of a toxic equivalency multiplier equal to 59. This number provides an estimate of the non-carcinogenic toxicity of the complex mixture of PCDDs and PCDFs compared with the concentration of 2,3,7,8-TCDD. This equivalency factor was also used to estimate carcinogenic equivalency as a worst-case assumption although such an application is speculative.

- Reductions in potential PCDD and PCDF concentrations in the environment due to volatilization or degradation or losses due to such actions as rainfall, were not considered.

- Exposure assessments were done for both indoor and outdoor exposure; although buildings may have filtering effect on airborne particles, indoor dioxin concentrations were assumed to be as high as outdoor ambient concentrations.

- Risks were calculated based on exposure for 24-hours a day, over a 70 year lifetime, at the point of maximum impact.

- No threshold for a safe level of dioxin exposure was assumed; any exposure to dioxin was assumed to pose some health risk. Moreover, of the accepted models for extrapolating the potential risk of very low level exposure, the most conservative model factor was used.

- Conservative assumptions for bioavailability, and rates of ingestions and dermal contact were included to estimate worst-case daily intakes of PCDDs and PCDFs.

The results of our risk analysis are summarized below. Maximum average ambient air concentrations were predicted for ground-level and elevated receptors assuming that all PCDDs and PCDFs are emitted as a gas. The maximum average annual ambient air concentrations are predicted to be well below existing standards and guidelines typically less than 1 percent. Only the NYSDEC performance guideline for evaluating combustion sources is approached, but at only 28 percent of the guideline.

Risks associated with inhalation of PCDDs and PCDFs at the maximum average annual concentrations were determined by comparing a predicted maximum daily intake through inhalation (DI_{inh}) with Acceptable Daily Intakes (ADIs) and cancer dose/ response extrapolations.

The maximum daily intake DI_{inh} of 2,3,7,8-TCDD, T_4CDD, and TCDD toxic equivalents are predicted to be well below (less than 1%) any ADI promulated by any regulatory agency. These ADIs provide a margin of safety and they identify a very safe dose, below which risks are insignificant for non-carcinogenic toxic effects.

An upper-bound to carcinogenicity risk was also determined by comparing DI_{inh} with three different cancer dose/response extrapolations. The upper-bound excess risk due to exposure to 2,3,7,8-TCDD and HCDD, at the point of maximum impact, ranges from less than .0019 to less than 0.055×10^{-6} or less than six cases per 100 million people exposed to the maximum concentration over a 70-year lifetime.

The sensitivity of the risk estimates derived for the inhalation pathway, to the additional risks that might be attributable to the ingestion and dermal pathways was tested. These two pathways were not considered in the initial risk assessment of the inhalation pathway due to the high degree of uncertainty in the estimates of ingestion, absorption, and bioavailability rates and due to the difficulties in modeling PCDD concentrations in soil, dirt and dust. A range of daily intake estimates was calculated (DI_{ing} and DI_{derm}).

For the low end of this range, the data indicate that the predicted additional 2,3,7,8-TCDD intake from ingestion or dermal absorption of particulate emissions from the BNYRRF would be negligible. Using worst-case assumptions regarding the maximum rates of exposure, the total daily intake of 2,3,7,8-TCDD would increase by 2.4 times the amount from inhalation alone. Under the "worst-case" scenario, ingestion becomes the major pathway of exposure.

The general conclusions regarding the level of risk posed by the BNYRRF are not significantly altered if the maximum total daily intake of 2,3,7, 8-TCDD increases 2.4-fold. This additional daily intake of 2,3,7,8-TCDD equals only 0.036% of the most conservative ADI (1.8 pg/kg-day) and a toxic equivalent daily intake which is only 2.1% of this ADI.

The upper-bound carcinogenic risk estimates will also increase by a factor of 2.4 assuming the most conservative estimates for the ingestion and dermal absorption pathways. This would result in an upper-bound increased cancer risk for a population exposed to the maximum 2,3,7,8-TCDD and HCDD concentrations over a 70-year lifetime ranging from .0046 x 10^{-6} to less than 0.13 x 10^{-6}.

As a further measure of conservatism, we examined the potential carcinogenic risks due to exposure to the complex mixture of PCDDs and PCDFs emitted from the BNYRRF for all three potential pathways of exposure.

Because no actual animal studies have been conducted to assess the carcinogenicity of most of the individual PCDD/PCDF isomers on the complex mixtures present in fly ash emissions another conservative assumption was made: that the carcinogenic effect of these compounds is equivalent to their toxic effect (i.e., that carcinogenic equivalency equals a toxic equivalency). However, this assumption is highly speculative. With these conservative assumptions, the maximum increased cancer risk due to the complex mixture of PCDDs and PCDFs present in the emissions ranges from less than 0.24 to an upper-bound limit of less than 5.9. x 10^{-6} for all these pathways combined.

In our opinion, within the context of the assumptions used in the risk assessment, and the conservative methods used to estimate risk, and considering current regulatory practice regarding acceptable versus unacceptable health risks, a worst-case upper bound excess cancer risk less than 5.9 x 10^{-6} is below levels found by many regulatory agencies to require additional review and probable action to reduce risk.

1.0 Introduction

1.1 Purpose

The purpose of this report is to provide an assessment of the potential health risks associated with the emission of polychlorinated dioxins (PCCDs) and furans (PCDFs) from the proposed Brooklyn Navy Yard Resource Recovery Facility (BNYRRF).

The report was composed through a literature search of existing information on dioxins and their emission from resource recovery facilities, supplemented by conversations with technical and regulatory authorities. The report is not, and was not intended to be, a product of original research.

Generally, the type of analysis contained in this report is included in the formal environmental impact statement for a point source of airborne pollution. However, in response to public concern over dioxin emissions and in view of the large population which could be affected by these emissions, New York City's Department of Sanitation was requested by the Board of Estimate to fund an independent study of the dioxin risks of the proposed BNYRRF.

1.2 Description of the Facility

Dioxin levels for the proposed BNYRRF were derived from the emission data of existing facilities using a mass-burn technology and an incinerator design similar to the proposed Brooklyn facility.

The proposed resource recovery facility is designed to handle 3,000 tons of minicipal waste each day. The plant will have four separate incinerators or combustion units, each sharing a 500-foot tall stack.

The system will utilize a mass-burn technology--burning raw minicipal solid waste without sorting or separation. It incorporates a Martin stoker system as has been used elsewhere in the United States, Europe, and Japan. The plant will also include a high-efficiency fabric filter and auxiliary burners designed to maintain a minimum temperature of 980° C.

1.3 Contents of the Report

This report contains an executive summary, this brief introductory chapter, and the scientific report contained in Chapters 2 through 6. Appendix C provides a discussion of some related issues.

Chapter 2 begins the scientific report with a discussion of the chemical and physical properties of dioxin and its toxicological effects. The presentation of dioxin's chemical and physical properties includes sections on both the sources of dioxin in the environment and the environmental fate of dioxin in the environment.

The section on toxicology considers human as well as animal data on the effects of dioxin. Both the toxic effects and the carcinogenic effects of dioxin are examined. Teratogenic, reproductive effects and mutagenic effects are also discussed.

Chapter 3 analyzes the literature regarding the emission of dioxins from different types of resource recovery facilities and incinerators. The chapter begins with a theoretical discussion of the mechanisms responsible for the formation of dioxin in incinerators. Requirements for the effective destruction of dioxins through incineration are also discussed.

These theoretical considerations are followed by a presentation of dioxin emission data from other resource recovery facilities using a mass-burn technology and an incinerator design similar to the proposed BNYRRF. As an important part of this discussion, the applicability of emission data from different facilities to the BNYRRF is discussed.

Chapter 3 concludes by describing the design of the BNYRRF and calculates the projected emissions from that facility.

Using the data presented at the conclusion of Chapter 3, the rates of dioxin dispersion and deposition throughout the New York City area are calculated in Chapter 4. Computerized models for the dispersion of airborne pollutants and their deposition were applied to BNYRRF emissions in order to estimate dioxin levels in the ambient air, soils, dust, and dirt at the point of maximum impact. These levels were then used as the basis for a risk assessment to evaluate risks at the point of maximum impact, assuming maximum exposure, 24-hours a day over a 70 year lifetime.

Chapter 5 evaluates risk from two perspectives. First, the risk from projected dioxin emission levels is compared to the existing acceptable levels defined by state, national, and international regulatory agencies.

In a second consideration of risk, the effects of projected emissions from the facility are estimated by comparing the "worst case" exposure levels to levels of dioxins known or suspected to have toxic or carcinogenic effects.

Chapter 6 places in perspective the upper limit to excess cancer risk predicted in Chapter 5. The projected risks are compared with risks inherent in everyday activities, with existing cancer incidence data, and with risks projcted from other routes and sources of dioxin exposure.

Appendix C provides an evaluation of additional methods that have been proposed for reducing dioxin emissions. It also contains an evaluation of the potential health risks associated with disposal of fly ash and bottom ash produced by incinerators and provides recommendations for future sampling.

1.4 Considerations in Risk Assessment

Several difficulties confront the assessment of hazards posed by the low-level PCDD and PCDF emissions from municipal waste-burning facilities. In general, data is sparse regarding such important factors as environmental fate, transport, uptake and bioavailability of PCDDs and PCDFs. Because of this lack of data, estimates, or a range of estimates, must be used to analyze risk.

A risk assessment frequently requires extrapolation of high dose animal feeding studies to estimate risk to humans at the extremely low dosages or concentrations of contaminants found in the environment. Data are not available to determine the actual shape of a dose/response curve (i.e., the level of risk), or the best method to extrapolate risk. Accordingly, there is a great range of uncertainty regarding actual risk (at very small concentrations) for a given contaminant.

Also complicating the assessment of dioxin hazards is the fact that although there are many different PCDDs and PCDFs, adequate toxicity data exists only for the most toxic isomer 2,3,7,8 TCDD, which represents less than 1 percent of these PCDD emissions. Evidence suggests that other PCDDs, and the PCDFs in general, are not as toxic as 2,3,7,8 TCDD.

. A risk assessment, however, should adopt some type of toxic equivalency to take into account the possible toxic effects of the complex mixture of PCDDs and PCDFs. Although there is some limited experimental data to quantify the toxic equivalency of the mixture for non-carcinogenic toxic effects, data is not available on the carcinogenic equivalency.

Due to the necessity of using estimates or assumptions, the degree to which predictions of risk conform to actual risk, (i.e., the quality of the assessment) can only be as good as the quality and degree of accuracy in the assumptions applied. Clearly, any assumptions used in risk assessment can have significant impacts on the overall findings and determination of levels of risk.

In the absence of sufficient data or knowledge about such issues as the degree of exposure, intake, fate and bioavailability of contaminants, the typical risk assessment uses the most reasonable assumptions possible, erring on the side of public health. Typically, "worst-case" scenarios or conservative assumptions are used in the assessment process to provide an added safety factor. A conservative assumption is one which increases the likelihood that a substance represents a hazard to public health.

To provide an element of conservatism, the following safety factors were incorporated into our risk assessment:

- Risks were calculated based on maximum 24 hours a day exposure, over a 70 year lifetime at the point of maximum impact.
- Assessment of three potential pathways of exposure: Inhalation of gaseous or particulate emissions, and ingestion or dermal absorption of particulates deposited on outdoor and indoor surfaces.
- Application of a toxic equivalency multiplier equal to 59. This number provides an estimate of the non-carcinogenic toxicity of the complex mixture of PCDDs and PCDFs compared with the concentration of 2,3,7,8-TCDD. This equivalency factor was also used to estimate carcinogenic equivalency as a worst-case assumption although such an application is speculative.
- No losses of PCDDs were assumed through volatilization or degradation or losses from such actions as rainfall.
- Indoor ambient air quality was assumed to equal outdoor air quality.
- The most conservative cancer risk extrapolation model was included to estimate an upper bound limit to increased cancer risk.
- Conservative assumptions for bioavailability, and rates of ingestions and dermal contact were included to estimate worst-case daily intakes of PCDDs.

However, the use of a number of "worst-case" or conservative assumptions carries the danger that the estimate or risk can become vastly overstated and therefore unrealistic. Risk assessments relying upon "worst-case" scenarios must be critically evaluated with regard to the degree of realism in the model used to estimate risk.

In reading and examining the risk assessment, it is important to remember that risk figures and calculations represent an "upper limit" to risk. They do not represent the most probable or average predicted risk level from dioxin emissions from the Proposed BNYRRF.

1.5 Technical Review

An important element on the preparation of this report was the selection of a panel of technical and scientific experts to provide independent review and ensure the accuracy and impartiality of the report.

The nine-member panel is composed of scientific, technical, and environmental experts from New York City and State, the United States and Europe. (A curriculum vitae for each panel member appears in Appendix E.)

Members include:

Thomas C. Chalmers, M.D.--President Emeritus, Dean Emeritus and Distinguished Service Professor at the Mount Sinai School of Medicine of the City of New York; Visiting Professor of Public Health and Management, Harvard School of Public Health.

Douglas Costle, J.D.--Former Regional Administrator, USEPA; former Chairman, U.S. Regulatory Council, and of the U.S. Radiation Policy Council; former Commissioner, State of Connecticut Department of Environmental Conservation.

Theodore Goldfarb, Ph.D--Associate Professor of Chemistry, SUNY at Stony Brook. Member of the review panel for the Hempstead, Long Island resource recovery facility; former Visiting Professor, Queens College Center for the Biology of Natural Systems. Expert in the environmental effects of various energy-producing technologies.

Raymond Harbison, M.D.--Professor and Director of the Interdisciplinary Toxicology Program at the University of Arkansas for Medical Research. Consultant to the USEPA on safety procedures for management of dioxin contamination at Times Beach, MO, and elsewhere. Member of the National Institute of Safety and Health advisory group, which is involved in dioxin-related issues.

Clark Heath, M.D.--Professor of Community Health, Emory University School of Medicine; community health consultant and former Program Development Officer, Centers for Disease Control.

Otto Hutzinger, Ph.D--Professor of Ecological Chemistry and Geochemistry, University of Bayreuth, Germany. Advisor on dioxin to: Ministry of the Environment, Canada, the National Research Council of Canada, the Ontario Scientific Advisory Committee on Dioxins and Furans; the Dutch Ministry of the Environment; the Ministry of the Environment, Rheinland Pfalz, and the German EPA; the USEPA.

Louis J. Thibodeaux, Ph.D.--Professor of Chemical Engineering, University of Arkansas. Has published extensively on the environmental fate and transport of dioxins and other chemicals.

Arthur Upton, M.D.--Professor and Chairman, Department of Environmental Medicine, New York University School of Medicine. Former Director, National Cancer Institute.

Charles Velzy, P.E.--President, Charles R. Velzy and Associates, Inc. Extensive experience in design and operation of solid waste incineration facilities and air pollution control technologies.

The panel met to review and comment on the proposed scope and approach of this report on February 28, and reconvened on April 29 to review the first draft. The written comments of the panelists on the final version of this report appear as Appendix D.

CHAPTER 2

Properties of Polychlorinated Dibenzo-p-dioxins

2.1 Background

2.1.1 Introduction

The purpose of this chapter is to provide a brief overview of the physical, chemical, and toxicological properties of polychlorinated dioxin relevant to this risk assessment. It is not an attempt to reiterate the literature on dioxin, but to provide information on the major concerns pertinent to this study.

Concern over polychlorinated dibenzo-p-dioxins arose when toxicological effects were noted as a result of the presence of TCDD in the widely used herbicide 2,4,5-T. 2,3,7,8-TCDD is formed as a contaminant during the production of 2,4,5-trichlorophenol from tetra-chlorobenzene and 2,4,5-T from 2,4,5-trichlorophenol. The major sources of polychlorinated dioxins in the environment are associated with the production, use, and disposal of chlorophenols and their derivatives. Polychlorinated dibenzofurans, (PCDFs) have been associated with the manufacture and destruction of polychlorinated biphenyls (PCBs). PCDFs also have been detected in emissions from combustion sources, primarily municipal and chemical waste incinerators. In addition, chlorinated dioxins have been reported in samples taken from incinerator stacks, chemical tar burners, and fossil-fueled power plants. One study reported trace amounts of dioxins in samples from vehicle mufflers, fireplaces, chimneys, cigarette smoke, and charcoal-broiled steaks (Bumb, 1980). Some of these data have been disputed and research is being conducted to refute or support the presence of dioxins in these sources.

The chemical, physical, and toxicological properties of PCDDs and PCDFs most relevant to this study include the following:

- PCDDs and PCDFs are present in the environment from several sources.
- PCDDs and PCDFs are resistant to chemical, physical, and biological degradation and thus are very stable in the environment.

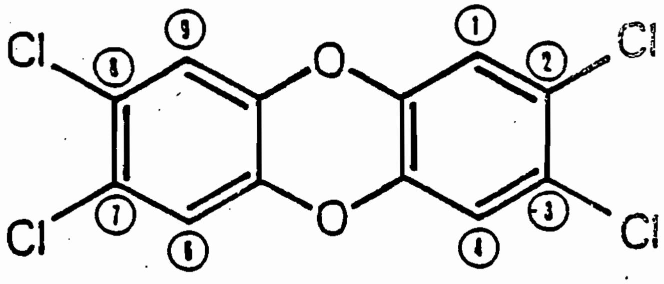
- PCDDs and PCDFs are lipid (fat) soluble and tend to bioconcentrate.
- PCDDs and PCDFs have an affinity for binding strongly to organic substrates, such as soil and sediment, and to fly ash.
- Due to the variability of environmental conditions and the complex chemical and physical properties of dioxins, the environmental half-life has been reported to range from one-half year up to twelve years.
- Dioxins, although not typically known as volatile compounds, may volatilize from soil surfaces in the environment. Evaporation may be a significant removal pathway.
- PCDDs and PCDFs are relatively stable to thermal destruction. Laboratory tests have demonstrated that dioxins are relatively stable up to a temperature of approximately 700°C and decompose at a temperature of approximately 800°C. Destruction efficiency varies with dwell time, temperature, mixing, availability of oxygen, and catalysts.
- At this time it is not clear whether PCDDs act as promoters or initiators of carcinogenesis.
- The toxicity of complex mixtures of PCDDs and PCDFs can be calculated using a toxic equivalency method based on the relative abilities of these compounds to induce microsomal enzymes.

2.1.2 Nomenclature

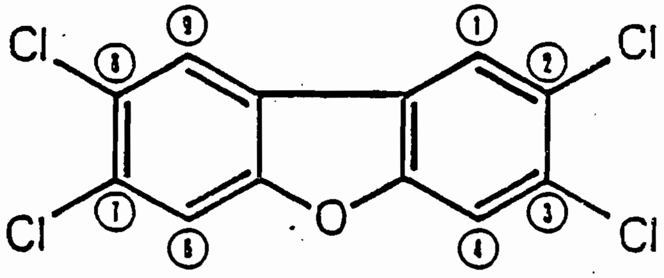
Polychlorinated dibenzo-p-dioxins (PCDDs) and dibenzofurans (PCDFs) are tricyclic organic compounds which exhibit similar physical and chemical properties. As shown in Figure 2-1, dioxins consist of two benzene rings connected by two oxygen atoms, while furans consist of two benzene rings connected by only one oxygen atom. The isomers of each compound differ only by the number and position of chlorine atoms around the benzene rings. Both dioxins and furans may contain from one to eight chlorine atoms.

There are 75 chlorinated dioxin congeners and 135 chlorinated furan congeners. The tetrachlorodibenzo-dioxin (TCDD) congener class has 22 isomers. Table 2-1 is a list of all chlorodibenzo-p-dioxins. Table 2-2 is a list of the abbreviations for the various chlorodibenzo-p-dioxins. For the purposes of this study, the following terms are defined:

FIGURE 2-1



2,3,7,8-TETRACHLORODIBENZODIOXIN



2,3,7,8-TETRACHLORODIBENZOFURAN

TABLE 2-1

A LIST OF POLYCHLORINATED DIBENZO-P-DIOXIN HOMOLOGUES BY CONGENER AND ISOMER (Number of isomers)

MONOCHLORO-(2)

1; 2;

DICHLORO-(10)

1,2; 1,3; 1,4;
1,6; 1,7; 1,8;
1,9; 2,3; 2,7;
2,8;

TRICHLORO-(14)

1,2,3; 1,2,4;
1,2,6; 1,2,7;
1,2,8; 1,2,9;
1,3,6; 1,3,7;
1,3,8; 1,3,9;
1,4,6; 1,4,7;
1,7,8; 2,3,7;

HEXACHLORO-(10)

1,2,3,4,6,7;
1,2,3,4,6,8;
1,2,3,4,6,9;
1,2,3,4,7,8;
1,2,3,6,7,8;
1,2,3,6,7,9;
1,2,3,6,8,9;
1,2,3,7,8,9;
1,2,4,6,7,9;
1,2,4,6,8,9;

TETRACHLORO-(22)

1,2,3,4; 1,2,3,6;
1,2,3,7; 1,2,3,8;
1,2,3,9; 1,2,4,6;
1,2,4,7; 1,2,4,8;
1,2,4,9; 1,2,6,8;
1,2,6,7; 1,2,7,8;
1,2,6,9; 1,2,8,9;
1,2,7,9; 1,3,6,9;
1,3,6,8; 1,3,7,9
1,3,7,8; 1,4,7,8;
1,4,6,9; 2,3,7,8;

PENTACHLORO-(14)

1,2,3,4,6; 1,2,3,4,7;
1,2,3,6,7; 1,2,3,6,8;
1,2,3,6,9; 1,2,3,7,8;
1,2,3,7,9; 1,2,3,8,9;
1,2,4,6,7; 1,2,4,6,8;
1,2,4,6,9; 1,2,4,7,8;
1,2,4,7,9; 1,2,4,8,9;

HEPTACHLORO-(2)

1,2,3,4,6,7,8;
1,2,3,4,6,7,9;

OCTACHLORO-(1)

1,2,3,4,6,7,8,9;

Source: NRCC, 1981.

TABLE 2-2

ABBREVIATIONS FOR VARIOUS CHLORODIBENZO-P-DIOXINS

Material or Material Group	Abbreviation
- for polychlorodibenzo-p-dioxins in general:	PCDD
- for tetrachlorodibenzo-p-dioxins in general:	TCDD
- for a specific tetrachlorodibenzo-p-dioxin, the 2,3,7,8 isomer, for instance:	2,3,7,8 TCDD
- for pentachlorodibenzo-p-dioxins in general:	P_5CDD
- for a specific pentachlorodibenzo-p-dioxin, the 1,2,3,7,8, isomer, for instance:	1,2,3,7,8 P_5CDD
- for hexachlorodibenzo-p-dioxins in general:	H_6CDD
- for heptachlorodibenzo-p-dioxins in general:	H_7CDD
- for octachlorodibenzo-p-dioxin:	OCDD

Source: Kemp, 1983.

- An isomer is defined by the numerical arrangement of chlorine atoms within the homologue.
- A homologue is defined as a group of isomers having a specified number of chlorine atoms; thus the tetrachloro homologue has 22 isomers.
- A homologue is a general term used to mean any isomer of any homologue; thus, there are a total of 75 PCDD congeners.

PCDFs use the same abbreviation system as PCDDs. For both PCDDs and PCDFs, the number and position of the chlorine atoms also may result in differences in chemical, physical, and biological properties.

2.1.3 Sources in the Environment

Polychlorinated dioxins and furans in the environment are associated with a variety of sources including manufacture of chlorophenols and chlorophenol derivatives, herbicide application, incineration of certain industrial wastes, chemical waste sites, municipal incinerators, and combustion of natural wood.

Incineration Sources. It has been shown that polychlorinated dioxins and furans are produced as contaminants from the incineration of municipal waste (NRCC, 1981; Lustenhouwer, et al., 1980). Emission rates are highly variable and may depend on the combustion methodology. It has been indicated that formation of chlorinated organic compounds is favored by poor combustion efficiency due to low temperatures and inefficient mixing (Somers and Douglas, 1983).

PCDDs, as well as PCDFs were first discovered on fly ash from municipal incinerators by Olie et al. (1977). Buser et al. (1978) then reported that PCDDs were present on the particulate matter from a municipal incinerator and industrial heating facility in Switzerland. Subsequent reports confirming the presence of PCDDs and PCDFs in combustion emission products include data from Canada, Japan, France, and the United States (Eiceman, et al., 1979, 1981; Karasek, 1980; Bumb, et al., 1980; Lamparski and Nestrick, 1980). PCDDs are also found in industrial incinerators where materials containing chlorinated phenols and polychlorinated diphenyl ethers are burned.

The greatest concentrations of PCDDs and PCDFs are associated with the smaller particles emitted in the flue gas of incinerators, since these particles have the greatest surface area (Lustenhouwer, et al., 1980; Ballschmiter, as reported by CARB, 1983; Kemp, 1983). Therefore, the larger particles collected by electrostatic precipitator (ESP) control devices do not have as high a concentration as the fine particles found in flue gas (ASME, 1981). Although some of the PCDD and PCDF emissions may be gaseous, the evidence indicates that a very significant amount is associated with fly ash or ultra-fine particulates.

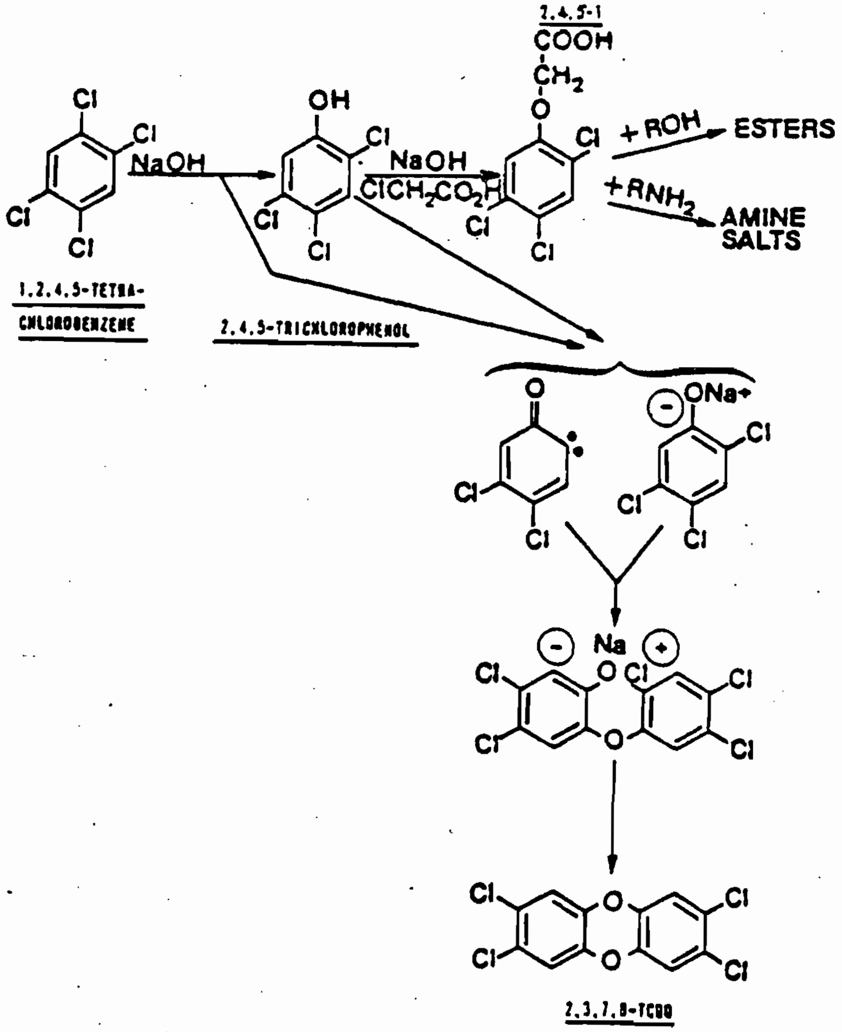
Manufacturing Processes. Dioxins are also inadvertently produced during the formulation of chlorinated phenols, and in chemicals utilizing the chlorophenols, such as 2,4,5-T and 2,4-D.

Chlorophenols may be produced by either the chlorination of phenols or by the alkaline hydrolysis of chlorobenzenes. Dioxins may be formed during either process. Polychlorinated dioxins may also be produced during the hydrolytic production of chlorinated benzenes, such as hexachlorobenzene (Esposito, et. al., 1980. 2,3,7,8-TCDD has been identified in commercial trichlorophenols, but is not associated with the manufacture of the pentachlorophenols (Josephson, 1983). Figure 2-2 shows the chemical reaction for the production of 2,4,5-trichlorophenol and 2,4,5-T and for the formation of 2,3,7,8-TCDD.

Herbicide Application. Agent Orange, which is a 1:1 mixture of the butyl esters of 2,4-D and 2,4,5-T has been shown to contain 2,3,7,8-TCDD at a range of concentrations from 0.1 to 47 ug/g. Dioxin was shown to originate from 2,4,5-T, and, as a result, efforts were made by manufacturers during the 1970's to control and minimize the formation of 2,3,7,8-TCDD. Producers have claimed that the products currently contain less than 0.1 ug/g (Rappe, et al., 1979). 2,4-D, however, became contaminated with TCDD because the equipment used to manufacture the 2,4-D was previously used to formulate dioxin-contaminated 2,4,5-T (Federal Register, 1980). The bactericide, hexachlorophene, also is prepared from 2,4,5-trichlorophenol and has been shown to contain trace amounts of TCDD (Rappe, 1984).

FIGURE 2-2

2,4,5-TRICHLOROPHENOL, 2,4,5-T AND ESTERS AND SALTS



Due to the presence of chlorinated dioxins, many of the domestic uses of 2,4,5-T, including use on home lawns, recreational areas, and food crops, were suspended by the USEPA in 1970. Use of 2,4,5-T in forests, on right-of-ways, and on turfs was restricted in 1979. The herbicide may still be used on rice fields, rangelands, industrial sites, vacant lots, parking lots, storage areas, fences, and hedgerows (Mays, 1984). Chlorinated dioxins have been found in foodgrade oleic acids, fleshing greases isolated from hides treated with PCP, and in some commercially available gelatin samples (Firestone, 1977). Hexa-, hepta-, and octa-CDDs and CDFs were found in samples of two kinds of latex nipples purchased in a Warsaw, Poland department store. Concentrations ranged from 0.03 ppb for hexa-CDD to 11.2 ppb for octa-CDD and 0.02 ppb for hexa-CDF to 3.1 ppb for hepta-CDF (Gorski, 1981).

Non-incineration Combustion Processes. Nestrick, et al. (1980) reported dioxins in samples from wood-fueled stoves and from the chimneys of wood-fueled furnaces. The samples were collected from rural areas of the United States where fuel wood was expected to have had minimal exposure to pesticides and herbicides and where no industrial or municipal incinerators were located nearby. The wood was not treated or processed. Concentrations of dioxins in the samples from the stoves were 170 ppt TCDD, 260 ppt HCDD, 330 ppt H_7CDD, and 210 ppt OCDD. Samples of chimney particulates around the region contained dioxin concentrations as high as 4,925 ppt for TCDD, and 12,400 ppt for OCDD. Levels of 2,3,7,8-TCDD as high as 100 ppt of 2,3,7,8-TCDD were also detected. Other samples showed no detectable levels of TCDDs and only 14 ppt of OCDD. Additional data suggest that the production of PCDDs from the combustion of natural wood may be a general phenomenon (Ahling, 1981; Tiernan, 1980).

In a recent study, Czuczwa and Hites found a series of chlorinated dioxins and furans in sediment samples from several locations in the Saginaw River, Saginaw Bay and Southern Lake Huron in Michigan. The levels ranged from 100 ppb near urban areas to 100 ppt in remote areas. The analytical profiles (isomer ratios) in the sediments corresponded closely to those found in samples from combustion sources. Analyses of sediment cores showed a dramatic increase in the levels of dioxin at a depth corresponding to a date of approximately 1940. The levels remained high for the more recent cores up until the present (Rappe, 1984). The concentrations over time also corresponded very closely to the production of chloro-aromatics and were concluded to be present as a result of combustion of these chlorinated organic products (Czuczwa and Hites, 1984).

Chemical Waste Sites. Other sources of dioxins in the environment are chemicals contaminated with dioxins which are awaiting disposal and disposal sites where dioxin - contaminated chemicals have been dumped. At a refuse dump near Amsterdam, wastes that were heavily contaminated with organochlorine compounds from 2,4,5-T production were disposed. Bottom sediments of a drainage ditch from the site contained 2,3,7,8-TCDD at concentrations of 50 ppt up to 5000 ppt (Heida, 1983).

Photochemical Processes. Photochemical processes also can lead to the formation of dioxins. Crosby and Wong (1976) have studied the dimerization of chlorophenols to octa-CDD. Lamparski, et al. (1980) have reported that photolysis of PCP-treated wood may form dioxins. Rappe, et al. (1979) has indicated that exposure of "predioxin" impurities in chlorophenols may produce chlorinated dioxins.

2.2 Physical and Chemical Properties

The physical and chemical properties of dioxins will determine how they will react in the environment, i.e. destruction, half-life, bioavailability, and transport.

2.2.1 Physical Properties

The physical properties of 2,3,7,8-TCDD and OCDD are shown in Table 2-3. These are lipophilic compounds and are only very slightly soluble in water. Lipophilic compounds are compounds which have an affinity for fats. As a result dioxins will tend to be absorbed in fatty tissue. In general, as the chlorine content of the PCDD and PCDF increase, their vapor pressures and water solubilities decrease and their octanol/water partition coefficients and solubilities in organic solvents increase (NRCC, 1981; IARC, 1977; ASME, 1981). The octanol/water partition coefficient is a general measure of a substances affinity for organic compounds or water. As a result of these properties, as the chlorine content of PCDDs and PCDFs increase, they generally are adsorbed onto an organic substrate, such as sediment, and volatilize less from water or wet surfaces.

It has been demonstrated that both PCDDs and PCDFs have a propensity for binding to soils, sediments, and fly ash (NRCC, 1981). The extent of this adhesion appears to be a function of the type of particulate matter in question and may be correlated with the percent carbon in the particle, the particle size, and the particle morphology (structure) (Barnes, 1983). This affinity is demonstrated further by the lengthy, difficult, and harsh sample preparation procedures used to extract dioxins and furans from fly ash. Kooke et al. (1981) used pretreatment with hydrochloric acid prior to extraction.

Based on knowledge of the physical properties of dioxins and on various laboratory experiments, it can be assumed that dioxins in fly ash increase in concentration with the surface area of the particulates and the corresponding large number of reactive binding sites. This is due to the fact that the ratio of surface area to weight increases as particle diameter decreases. The strong affinity of dioxins for organic matter and fly ash will make them less bioavailable.

2.2.2 Chemical Properties.

In general, dioxins are relatively stable toward harsh treatment with acids, bases, and heat and are stable to chemical oxidation and reduction (NRCC, 1981). Heat treatment with alkali will, however, destroy octa-CCD (Albro, 1979). The chlorinated dibenzodioxins appear to be fairly resistant to thermal degradation. From kinetic and thermodynamic principles, Shaub and Tsang (1983) estimated that 99.99 percent destruction of TCDDs in the gas phase at 727°C may require about 15 minutes. At 977°C, however, the decomposition may require less than one second. PCDDs may photodecompose to produce less chlorinated species. According to a study by Buser and Rappe

(1978) it is unlikely that the most toxic isomers (i.e., 2,3,7,8,-TCDD) will be formed through the photolysis of the higher PCDDs. Dioxin also will undergo photoreductive dechlorination (loss of chlorine in the presence of light) in the presence of a hydrogen donor (Crosby and Wong, 1977). This is the general mechanism for photoreaction.

2.3 Environmental Fate

As a result of the strong chemical stability of the dioxins, as demonstrated under severe laboratory conditions, it is expected that destruction under environmental conditions would be very slow.

2.3.1 Environmental Half-Life

The half-life of 2,3,7,8-TCDD in soil has been reported to range from one-half year up to twelve years (Kearney *et al*., 1972; IARC, 1977; Young, 1983; Di Domenico *et al* ., 1980). Based on these studies it can be concluded that the environmental half-life of dioxins is a complex issue and a general half-life cannot be used because too many variable conditions exist. This was further substantiated by a study by Freeman and Schroy (1984) of contaminated oil sprayed on Times Beach soil in 1973. A model was developed based on actual soil samples collected ten years after spraying. It was determined that a simple half-life model was inadequate due to temperature fluctuations throughout the year. As a result of this study the following conclusions were drawn:

- Volatilization of TCDD may be a major removal pathway.
- Temperature is the driving force behind the transport of TCDD into and from the soil column.
- TCDD will volatilize from soils most rapidly during summer months, but not to any appreciable extent during winter months.
- Over 50 percent of the total applied TCDD volatilized during the first summer after initial application at Times Beach.
- Over 90 percent of the applied TCDD volatilized from the top 1 cm of soil during the first summer.

TABLE 2-3

PHYSICAL PROPERTIES OF TWO CHLORINATED DIOXINS

		2,3,7,8-TCDD	OCDD
Empirical formula		$C_{12}H_4Cl_4O_2$	$C_{12}Cl_8O_2$
Percent by weight	C	44.7	31.3
	O	9.95	7.0
	H	1.25	
	Cl	44.1	61.7
Molecular weight		322	459.8
Melting point, °C		305	130
Description		Colorless Needles	Colorless Solid
Decomposition temperature, °C		Above 700	Above 700
Solubilities, gram/liter			
O-Dichlorobenzene		1.4	1.83
Chlorobenzene		0.72	
Anisole			1.73
Xylene			3.58
Benzene		0.57	
Chloroform		0.37	0.56
n-Octanol		0.048	
Methanol		0.01	
Acetone		0.11	
Dioxane			0.38
Water		0.000000 (0.2 ppb)	
Vapor pressure [a] (mm of Hg)		1.7×10^{-6} 1×10^{-6}	-
Octanol/Water Partition coefficient		1.4×10^6 6.9×10^6 1.9×10^7	-
Sorption partition Coefficient (K_{oc})		9.9×10^5 3.3×10^6	

Sources: (NRCC, 1981; USEPA, 1981, Esposito, 1980)

[a] Freeman and Schroy (1984) have reported a lower vapor pressure of 1.5×10^{-9} mm Hg at 25°C.

By analogy with this soil study, it can be anticipated that dioxin in fly ash will not build up infinitely in the environment but will volatilize over time at some yet undetermined rate.

Photolytic degradation may be another mechanism for removal of dioxins from the environment. According to a study by Crosby and Wong (1977), 2,3,7,8-TCDD will photolyze in sunlight in the presence of a hydrogen donor, i.e., methanol. Dioxin also may photolyze in surface waters. However, dioxins adsorbed onto particulate matter or sediment may be unavailable for degradation by photolysis. Although an increase in chlorine content may tend to decrease photodegradation, the position of the chlorine atoms on the molecule may be critical (Nestrick *et al.*, 1981; Crosby *et al.*, 1971). Preferential loss of chlorine has been demonstrated to be from the 2,3,7, and 8 positions (Nestrick *et al.*, 1981). Since the photodegradation of dioxin varies with the exposure to sunlight and the availability of a hydrogen donor, it is not expected that a simple model for the photolytic half-life of dioxins can be developed.

2.3.2 Air

Polychlorinated dioxins are likely to be removed from the atmospheric environment by wet and dry deposition of particulates and by photodegradation. Dioxins also may volatilize from particles and surfaces although they have low vapor pressures. Nash and Beall (1980) have demonstrated volatilization of TCDD from soil in both field and environmental chamber studies. Although they found the rate of evaporation to be low, they detected TCDD in air during a microcosm experiment approximately 8×10^{-11} g/m^3 on Day 0 to 1.6×10^{-14} g/m^3 on Day 203.

Photolysis appears to be the most significant natural destructive mechanism for removing dioxin from the environment, although the extent to which this occurs is difficult to assess (Esposito, 1980). Higher chlorinated isomers have been determined to degrade to less chlorinated isomers. 2,3,7,8-TCDD has not been detected in the decomposition products since chlorine atoms in lateral positions are removed preferentially. Degradation has been documented by many laboratory studies and was found to range from 0% of TCDD crystals on a glass plate exposed to sunlight for 14 days up to

50% of TCDD in isoctane and 1-octanol irradiated for 40 minutes under an artificial sunlamp. Results of various studies are summarized in Table 2-4.

Based on available laboratory and field data, it can be assumed that dioxins which have volatilized from particles or surfaces would be more susceptible to photolytic degradation than dioxins adsorbed on particles.

2.3.3. Water

Polychlorinated dioxins may enter the aquatic environment through leaching of chemical dumps, industrial effluents, atmospheric fallout of contaminated particulates, and erosion of contaminated soil (Esposito, 1980). The ultimate sinks for PCDDs include aquatic systems. Since PCDDs have very low solubilities and bind rapidly and strongly to soils or sediments, actual concentrations in water will be low (NRCC, 1981). Matsumura and Ward (1976) showed, that after separation from lake-bottom sediment, water contained 0.3 to 9% of the original dioxin added to the sediment (Esposito, 1980).

The mechanisms for removal of polychlorinated dioxins from water include adsorption, volatilization, photodegradation, biodegradation, and bioaccumulation. Adsorption to sediment and suspended particles is expected to be the primary means of removal of 2,3,7,8-TCDD from water (ASME, 1981). More than 90% of 2,3,7,8-TCDD in an aquatic environment may be present in the adsorbed state (Ward and Matsumura, 1978; Matsumura _et al_., 1983). Some removal also may be attributed to volatilization, but highly organic sediments and suspended solids may reduce this process. Reducing the organic matter in water from 10 percent to one percent may reduce the residence time of dioxin in the aquatic environment from seven years to one-half year (NRCC, 1981). Ward and Matsumura (1978) observed that the half-life of 2,3,7,8-TCDD in lake waters with sediment was 550 to 590 days. The half-life in waters without sediment was longer. The shorter half-life was probably due to the adsorption of dioxin from the water onto the sediment.

There is some evidence that TCDD is metabolized very slowly in sediment and the metabolites are released into the water. Aquatic plants may uptake most of the TCDD and release it back into the sediment when they die (Matsumura, _et al_., 1983). Of approximately 100 strains of microorganisms known

TABLE 2-4

PHOTODEGRADATION OF 2,3,7,8-TCDD

Physical Conditions	Light Source	Length of exposure	Amount degraded (%)	Reaction products	Reference
TCDD in methanol	Natural sunlight	7 h	100	NR	Crosby et al., 1971
TCDD (crystalline) in water	Artificial (sunlamp)	NR	0	NA	Crosby et al., 1973
TCDD crystals on glass plate	Natural sunlight	14 days	0	NR	Crosby et al., 1971
TCDD in Herbicide Orange, on glass	Natural sunlight	6 h	60		Crosby and Wong, 1977
TCDD in Herbicide Orange, on plant leaves	Sunlight	6 h 6 h	100 70		Crosby and Wong, 1977
TCDD in Herbicide Orange, on soil	Sunlight	6 h	10		Crosby and Wong, 1977
TCDD in Seveso soil with ethyl oleate-xylene mixture	Sunlight artificial	7 days 3 days	90 100	NR	Bertoni, 1978

NR = Not Reported
NA = Not Applicable

SOURCE; Esposito, 1980

to degrade persistent pesticides, only five were shown to degrade 2,3,7,8-TCDD slightly under laboratory conditions (USEPA, 1981). Biodegradation of dioxins in the environment under natural conditions does not appear to be a major degradation pathway.

2.3.4 Soil

According to Thibodeaux (1984), the active mechanisms influencing the fate of dioxin emissions from an incinerator are atmospheric fallout, evaporation, photodegradation, particle resuspension by wind, runoff by water, and bioturbation into underlying soil layers. Bioturbation is defined as the mixing of the upper layers of soil or sediment by the community of organisms that reside on or near the surface. In urban environments, human activity would be more significant in mixing dioxins into the soil than bioturbation. Dioxins have a higher affinity for soil than they do for water and, therefore, will not migrate substantially into soil. According to a theoretical equation developed by Karickhoff et. al. (1979), a soil/water partition coefficient of 4.8×10^4 for 2,3,7,8-TCDD was predicted for a soil containing only 10% organic matter (NRCC, 1981). This indicates that although a soil may be poor in organic matter, the dioxin has an affinity for the soil of approximately 50,000 times greater than for water. Dioxins applied to the surface of soils having a high organic content generally remain in the upper six to twelve inches of the soil. In more sandy soils, they migrate to three feet or more (Thibodeaux, 1983). Lateral movement of TCDD in soil may occur via erosion or through contaminated airborne dust (USEPA, 1981; Helling, et. al., 1973). Vertical movement in soil may occur due to saturation of the sorption site of the soil matrix, migration by organic solvents (NRCC, 1981), human activity, or bioturbation (Thibodeaux, 1984). Vertical migration may be enhanced by heavy rainfall.

Photolysis of TCDD in soil was found to be less than for other substrates, possibly due to a shading effect (Crosby and Wong, 1977). In urban areas, shading from buildings and other objects will reduce photodegradation even more. However, in a small scale study in Seveso, Italy, a hydrogen donor in an aqueous solution was applied to a heavily dioxin-contaminated area of grassland in order to enhance photodegradation. After nine days, 80 to 90 percent of the 2,3,7,8-TCDD was destroyed (Wipf et al., 1978; Crosby, 1978).

According to Thibodeaux (1984) and Freeman and Schroy (1984), dioxins may volatilize from soil surfaces to an appreciable extent, especially during summer months. Volatilization during winter months would not be expected to be significant. Most of the volatilization would occur from the uppermost surface of the soil.

Microbial attack of TCDD in soil was found to be very slow under laboratory conditions. Only approximately one percent was transformed to an assumed metabolite of TCDD within several months of incubation (Hutter and Philippi, 1982). Innoculation with favorable organisms or enrichment with nutrients had no effect on stimulating the microbial degradation of 2,3,7,8-TCDD in contaminated soils (Pocchiari, 1978). In addition, laboratory data show that addition of organic compost to contaminated soil had no appreciable influence on the degradation of TCDD (Camoni, _et_ _al_., 1982). Therefore, it is expected that biodegradation of dioxins in the soil environment is insignificant.

2.3.5 _Summary_. Polychlorinated dibenzo-p-dioxins are produced largely as unwanted contaminants from the manufacture of trichlorophenols and the herbicide, 2,4,5-T. In addition, both chlorinated dioxins and chlorinated furans are associated with a variety of combustion sources. Little is known about the actual fate of dioxins in the environment and the data are conflicting. Dioxins are relatively persistent compounds which are comparatively stable to environmental degradation. They have an affinity for binding to soils, sediments, and particulate matter, such as fly ash. Since dioxins are not very water soluble and they bind to soils, they do not migrate substantially either vertically or horizontally. Volatilization from soils through vapor phase transport is dependent on ambient temperature and is thought to be a major removal pathway. The half-life of dioxin in soil depends on complex environmental conditions and has been reported to range from one-half year up to twelve years. The primary removal mechanism of dioxin from water is through adsorption by sediment or biota, although volatilization and photodegradation may occur to some extent. Polychlorinated dioxins in the atmosphere are present in the particulate-sorbed or vapor phase state. They may be removed from the air by atmospheric deposition or photochemical degradation.

2.4 Toxicology

The toxicity of polychlorinated dioxins is a critical factor in evaluating the potential risks related to emissions from the proposed BNYRRF. The following sections address the principal concerns and issues surrounding the toxicity of PCDDs, present summaries of major animal and human toxicological studies, and discuss the carcinogenicity, teratogenicity, mutagenicity, and toxicity mechanisms of these materials.

2.4.1 Principal Concerns and Issues

In examining the risks associated with the BNYRRF, several major issues pertaining to the toxicology of PCDDs will be discussed.

Type of Effects. Animal and human studies ascribe both acute (short-term) and chronic (long-term) effects to exposure to PCDDs. Although short-term effects have been noted at high doses, the major concern associated with the BNYRRF is the potential for chronic effects following extended exposure to low levels.

Scarcity of Data on Human Toxicology. Most of the information pertaining to the toxicity of PCDDs is derived from animal studies. While these studies do not provide direct estimates of risks to humans, properly conducted, they can yield results which can improve estimates of the risk to human populations. At the same time, however, there are difficulties in extrapolating results of these studies from animals to humans (NAS, 1977).

- Humans, unlike laboratory animals, are not genetically homogeneous. These differences in genetic makeup, particularly genetic differences in metabolism, can affect human responses to toxicity.
- The environment in a laboratory experiment is strictly controlled, while humans are exposed to a wide range of environmental conditions, including intake of chemicals in addition to the ones under study.
- Differences in life span, size, weight, and metabolism between test species and humans present problems in dose vs. duration. Since humans generally excrete compounds more slowly than rodents, humans, with a small daily intake, can develop a higher accumulation of a compound over a number of years.

In areas where human data is insufficient, the BNYRRF risk assessment utilizes information obtained from animal studies, primarily in the areas of bioavailability through ingestion and dermal exposure. (Piper et al., 1973; Fries and Marrow, 1975; Rose et al., 1976; Nolan et al., 1979).

Animal data was also utilized in the calculation of upper-bound cancer risk estimates. These risks are derived from models which utilize extrapolations from high dosage carcinogenic animal bioassays. The models apply a conversion factor, based on relative weights or surface areas, to convert animal dosage to human dosage.

Promoter vs. Initiator of Carcinogenesis. Potentially cancer-causing compounds can cause carcinogenesis through initiation or promotion of tumor formation. A promotor is defined as an agent which results in an increase in cancer induction after long-term application subsequent to treatment of an animal with an initiator. Under otherwise identical conditions, neither initiator nor promoter alone induces many tumors. Some initiators are capable at high doses, however, of producing a carcinogenic effect without the addition of a promoting agent.

Although 2,3,7,8-TCDD is carcinogenic to animals, it is not clear whether it can act both as an initiator and as a promoter of carcinogenesis. One study (Pitot et al, 1980), shows that 2,3,7,8-TCDD is a potent promoter of liver cancer after initiation with diethylnitrosamine. Another study indicates a potent promoter effect using 3-methyl chloranthrene as an initiator (Kouri et al, 1978). Other investigations, however, have produced negative results (NTP, 1980b; Berry et al, 1979). This issue currently remains open to question.

There are, however, relatively little data to suggest that 2,3,7,8-TCDD is an initiator of carcinogenesis. In the risk assessment, a linear non-threshold model is used to extrapolate risk. This model is believed to overestimate risks for carcinogens which act as promoters, hence the risks derived in Chapter 5 may be overstated.

Toxicity and Carcinogenicity of Complex Mixtures. One of the critical issues pertaining to the BNYRRF is the toxic and carcinogenic potential of the complex mixture of PCDDs which will be emitted.

Given the difficulties in assessing the potential synergistic and antagonistic effects of mixtures, the concept of toxic equivalency has been developed. Briefly stated, toxic equivalency assigns a value to the toxicity of a mixture by evaluating the relative ability of the isomer components to induce microsomal enzymes and initiate a toxic effect. The ability of PCDDs to induce enzymes is discussed in Section 2.4.7 and the method used to calculate toxic equivalency is presented in Chapter 5.0.

2.4.2 Animal Toxicology.

As previously stated, acute and chronic animal studies provide most of the current data regarding the toxicity of PCDDs. Most of this information pertains to 2,3,7,8-TCDD, the most widely studied of these compounds. Table 2-5 outlines the characteristics of both acute and chronic toxicity testing. Relative toxicities for the various PCDD isomers are provided in Table 2-6. The major focus of the risk assessment is long-term effects due to prolonged low doses. Therefore, the following sections will emphasize chronic effects.

Acute Lethality. 2,3,7,8-TCDD has been demonstrated to be acutely toxic to a variety of animal species. In acute toxicity studies, the test chemical is administered in a single dose, and the endpoint is the LD_{50}, the dose causing death in 50 percent of the test animals. Several characteristic features of acute 2,3,7,8,-TCDD toxicity include:

- Considerable variation in toxicity (LD_{50}s) among species. The LD_{50} of 2,3,7,8-TCDD ranges from 0.6 ug/kg-body weight in the most sensitive species, (the guinea pig), up to approximately 5000 ug/kg-b.w. in the hamster. Toxicity to mice, monkeys, and rabbits falls near the middle of this range. LD_{50}'s for several test species appear in Table 2-7.
- Varying effects among test species. TCDD causes a number of similar acute toxic effects in different test animals. Nearly all test animals lose body fat and show involution (shrinkage) of the thymus and atrophy of the body tissues. Other effects, however, are not found in all species. Chloracne, a clinical marker of human dioxin exposure, also occurs in some mice, rhesus monkeys, and rabbits. It has not been observed in guinea pigs, hamsters and some test strains of mice.
- Delay between dose and effect. The toxic effects of TCDD develop slowly when compared with those from other highly toxic materials. Depending on the test animal, the interval between exposure and

TABLE 2-5

AN OUTLINE OF ACUTE AND CHRONIC ANIMAL TOXICOLOGIC TESTS

I. Acute Tests (single dose)

  A. LD_{50} determination (24-hour test and survivors followed for 7 days)

    1. Two species (usually rats and mice)
    2. Two routes or administration (one by intended route of use)

  B. Topical effects on rabbit skin (if intended route of use is topical; evaluated at 24-hours and at 7-days)

II. Chronic Tests (daily doses)

  A. Duration - 2 to 7 years depending on species
  B. Species--selected from results of prior prolonged tests, pharmacodynamic studies on several species of animals, possible single dose human trial studies. Otherwise use of two species.
  C. Minimum of two dose levels.
  D. Route of administration according to intended route of use
  E. Evaluation of state of health

    1. All animals weighed weekly
    2. Complete physical examination weekly
    3. Blood chemistry, urinalysis, hematologic examination and function tests on all animals at 3- to 6-month intervals and on all ill or abnormal animals

  F. All animals subject to complete autopsy including histologic examination of all organ systems.

Source: Adapted from Loomis, <u>Essentials of Toxicology</u>

TABLE 2-6

RELATIVE TOXICITY OF VARIOUS PCDDs AS INDICATED BY SEVERAL TESTS

Material	AHH Induction Relative to 2,3,7,8 TCDD	Acute Lethality Vertebrates LD50[a]	Carcinogenicity Rat-Minimum Observed Dosage[b]	Reproductive Minimum Observed Dosage in Rat[b]	Teratogenic Minimum Observed Dosage in Rat[b]
2,3,7,8 TCDD	1	0.6 - 5,000	1×10^{-2}	1×10^{-1}	
1,2,3,7,8 P_5CDD	15	3 - 338			
1,2,3,4,7,8 H_6CDD	21	70 - 800	36×10^{-2}	100	1-10
1,2,3,6,7,8 H_6CDD	85	70 - 1,300			
1,2,3,7,8,9 H_6CDD	130	60 - 1,400			
1,3,7,8 TCDD	240				
1,2,3,4,6,7,8 H_7CDD	370	600 -			
1,2,3,8 TCDD	1,700				
2,3,7 T_3CDD	3,000	30,000 -			
1,2,3,4,6,7,9 H_7CDD	10,000				
1,2,3,4 TCDD	33,000	- 1,000,000			800,000 +
2,8 DCDD	33,000	300,000 -			
2,7 DCDD	33,000	- 2,000,000			100,000 +
O_8CDD	53,000	- 1,000,000			
1,2,3,6,7 P_5CDD	220,000				
1,2,4,7,8 P_5CDD	330,000	1,000 - 5,000		500,000	

a nanograms per gram of body weight; a number preceding the dash (-) is for guinea pig (the most sensitive of experimental animals) and a number after the dash is the highest LD50 for any vertebrate tested for acute toxicity to PCDDs.

b nanograms per gram of body weight per day.

Source: NRCC, 1981.

TABLE 2-7

LD_{50}S FOR SEVERAL ANIMAL SPECIES

Species	Sex	LD_{50}(ug/kg-bw)
Guinea Pig	M	0.6 - 2.1
	F	3
Rabbits	Mixed	115
Rat, Sherman	M	22
	F	45
Rat, Charles River	Mixed	100
Rat, Porton	F	190
Mouse	M	114
Dog	Mixed	300-3,000
Monkey, Rhesus	F	70

Source: Harding, 1982

death ranged up to 45 days. During this interval, test animals exhibit a general wasting syndrome, associated with poor weight gain or loss of weight. This effect appears to be unrelated to food intake. (Poland and Glover, 1980). Mean time to death was unaffected by increasing the dose of 2,3,7,8-TCDD. (McConnell *et al*., 1978).

Chronic Non-Carcinogenic Effects. Four major feeding studies have been performed in order to assess the chronic effects of 2,3,7,8-TCDD. These studies involve administration of the test chemical on repeated occasions over a substantial portion of the lifetime of the test animal.

Although most long-term studies of 2,3,7,8-TCDD were designed to evaluate its carcinogenic potential, these investigations have also produced some data regarding non-carcinogenic toxic effects. These effects included reduced survival rates (Van Miller *et al*., 1977, Kociba *et al*., 1978), toxic hepatitis (NTP, 1980), dermatitis (Toth *et al*., 1978, 1979). Table 2-8 presents an overview of the chronic effects observed in animal studies.

Chronic toxicity data from these long-term studies are used to derive the NOEL (No Observed Effect Level) and ADI (Acceptable Daily Intake) that are utilized in the risk assessment. The ADI applies a safety factor to the NOEL.

2.4.3 Human Toxicology

The bulk of the data regarding human exposure to 2,3,7,8 TCDD derives from accidental exposures of workers or the general population. Most cases involved exposure to a mixture of chemicals, thus enabling only inexact estimates of TCDD exposure. In addition, these mixed exposures make it difficult to relate symptoms solely to effects of TCDD. In general, symptoms observed during these incidents include (NRCC, 1981):

- skin lesions, including chloracne, hyperpigmentation and thickening of the skin

TABLE 2-8

CHRONIC EFFECTS IN VARIOUS ANIMAL SPECIES

Symptom	Monkey	Guinea pig	Cow	Rat	Mouse	Rabbit	Chicken	Hamster
Abnormal cell proliferations or organ enlargement								
Gastric mucosa	++	0	+	0	0			0
Intestinal mucosa	+							++
Urinary tract	++	++	++	0	0			
Bile duct/gall gladder	++		+		++			
Lung				++				
Skin	++		a	0	0	++		
Atrophy or decreased cell proliferation								
Thymus	+	+	+	+	+		+	+
Bone marrow	+	+			+		+	
Testicle	+	+		+	+		+	
Other Effects								
Liver lesions	+	0		++	+	+	+	+
Edema	+	0		0	+		++	+

Note: 0 - Indicates lesion not observed;
+ - Indicates lesion observed (number of plusses notes severity)
a - Skin lesions are observed in cattle, but they are different from the lesions seen in other species.

Source: Poland and Knutson, Annual Review of Pharmacology & Toxicology, 1982.

- hair loss and hirsutism (excessive hair growth)
- porphyria cutanea tarda
- central and peripheral nervous disorders
- liver, kidney and gastrointestinal disturbances
- neurasthenia, including lack of drive and vigor, sleep disturbances, emotional instability and altered basic frame of mind
- respiratory and cardiac disorders
- hypothyroidism

Reggiani (1983) tabulates a more extensive list of effects which have been observed in persons exposed to products containing halogenated dioxins (Table 2-9).

Acute. Several instances of acute human exposure are discussed in the following sections.

Oliver (1975) performed a clinical assessment of three scientists involved in two laboratory accidents in which an undetermined quantity of PCDD was released. The two scientists involved in one incident developed chloracne within three weeks and one displayed gastrointestinal problems, fatigue, headaches, and some neurological effects. The third scientist, exposed in a second accident, did not develop chloracne, but did show signs of excess hair growth, lack of coordination, and blurred vision. Most of these symptoms subsided over time.

A number of industrial accidents have been associated with acute symptoms in worker populations. Holmstedt (1980) and Zack and Suskind (1980), investigating five separate incidents reported chloracne as the major effect. Other symptoms noted in some cases included nervous system and internal organ damage, abnormal liver function, and altered blood parameters.

TABLE 2-9

ACUTE AND CHRONIC HUMAN HEALTH EFFECTS OF HALOGENATED DIOXINS AND RELATED COMPOUNDS

System or finding	Signs of lesion	Chemical Product
Skin	Chlor- or bromacne, hyperpigmentation, hair loss, nail growth, porphyria	Penta- and hexachloronaphthalenes, tetrachlorodibenzofuran, hexa- and heptachlorobiphenyls, tetrabromodibenzofuran, polybrominated naphthalene
Hepatic	Liver enlargement, impaired liver function fatty degeneration, fibrosis, hepatocellular necrosis	Chlorinated naphthalenes, tetrachlorodibenzo-dioxin, technical pentachlorophenol
Respiratory	Reduced vital capacity, chronic bronchitis	Technical pentachlorophenol, polychlorinated and polybrominated biphenyls
Central and peripheral neurological	Muscle and joint pain, numbness and spasm in the limbs, reduced sensory and motor conduction velocity, sensory disturbances (taste, hearing, smell, sight impairment)	Polychlorinated biphenyls, -dibenzofurans, -dibenzodioxin
Endocrine system	Irregular menstrual cycle, retarded growth	Polychlorinated biphenyl and -dibenzofurans
Ocular manifestations	Several degrees of inflammation with burning, discharge, edema of eyelid, cyst formation of tarsal glands and pigmentation of eyelid and conjunctiva	Technical pentachlorophenol, polychlorinated biphenyls, -dibenzofurans and -dibenzodioxin
Stomatological alterations	Pigmentation of oral mucosa, anomalies in number and growth of teeth	Polychlorinated biphenyls and -dibenzofurans

TABLE 2-9 (Continued)

ACUTE AND CHRONIC HUMAN
HEALTH EFFECTS OF HALOGENATED DIOXINS AND RELATED COMPOUNDS

System or finding	Signs of lesion	Chemical Product
Clinical chemistry laboratory findings	Increased serum triglycerides, decreased serum bilirubin	Polychlorinated biphenyls, -dibenzofurans and -dibenzodioxins

Source: Reggiani, 1983

The most extensively studied release of TCDD occurred in Seveso, Italy in 1976. Workers and residents, exposed to the contents of an exploded reactor, developed chloracne, nausea, vomiting, headaches, diarrhea, excessive sweating, and eye irritation. Most of these symptoms were reported within several weeks. Pocchiari _et_ _al_., (1979) cites data which report some neurological effects. Most of these acute effects, in particular chloracne, had healed within three months after the incident. The 15 cases characterized as "severe" healed within five years. (Wipf and Schmid, 1983).

Effects of exposure of up to 30 ppm of 2,3,7,8-TCDD in soil in horse arenas was documented by Kimbrough _et_ _al_. (1977). A six-year-old child developed headaches, diarrhea, nosebleeds and lethargy. Two small boys developed skin rashes, while three other persons suffered from headaches, skin lesions and pain in some joints. The six year old was reexamined five years later and showed no sign of residual toxicity (Beale, et. al, 1977).

Chronic. Long-term contact with TCDD is primarily due to occupational exposures during the use or manufacture of TCDD-containing products. Results of several studies of chronic exposure are outlined in Table 2-10.

In recent years, past exposure of Vietnam veterans to Agent Orange has received a great deal of attention. Agent Orange (Herbicide Orange) is a 1:1 mixture of 2,4 dichlorophenoxyacetic acid (2,4-D) and 2,4,5-trichlorophenoxyacetic acid (2,4,5-T) which was used in Southeast Asia during 1965-1972. This material is contaminated with 2,3,7,8-TCDD in amounts ranging from 0.02 to 15 ppm (AMA, 1981). TCDD was also a contaminant of the approximately 276,000 gallons of Agents Green, Pink, and Purple, which were used in Vietnam from 1962 through 1964.

A number of Vietnam veterans who may have been exposed to Agent Orange have complained of various effects. Many of the reported symptoms (nausea, joint pains and stiffness, headaches, dizziness) are difficult to ascribe to TCDD exposure due to their non-specificity and widespread occurrence in the general population. Follow-up studies on these personnel have not, as yet, shown a significant increase in TCDD-related symptoms. A number of other studies are ongoing.

TABLE 2-10

STUDIES OF OCCUPATIONAL EXPOSURE TO 2,3,7,8-TCDD

Author(s) (date)	Type of Exposure	Reported Effects
Poland *et al.* (1971)	Manufacture of 2,4,5-T	Chloracne, acne, eye irritation, hyperpigmentation, hirsutism, gastrointestinal effects
Walker and Martin (1979)	exposure to 2,3,7,8-TCDD	elevated triglyceride levels, abnormal lipid levels
Ott (1980)	manufacture of 2,4,5-T (22 months)	No reported effects
Cook *et al.* (1980)	manufacture of trichlorophenol	chloracne
Pazderova Vejlupkova (1981)	manufacture of 2,4,5 sodium trichlorophenoxyacetate and trichlorophenoxyacetate butyl ester	Hypercholesteremia, hyperlipemia, hyperphospholipemia, increased plasma alpha and gamma globulins, and decreased plasma albumin 5 years after exposure - abnormal lipid metabolism and glucose tolerance and high urinary excretion of uroporphyrins

Much of the current knowledge regarding chronic effects of TCDD exposure in humans has resulted from data gathered in the aftermath of the Seveso incident. In 1976, uncontrolled exothermic reactions in a trichlorophenol reactor released a mixture of trichlorophenol and reaction products, including up to several pounds of 2,3,7,8-TCDD. Approximately 37,000 people were exposed to these materials. Two years later the resultant health effects were assessed. The chloracne, which had occurred primarily in children, had healed. Subclinical neurological and liver effects remained, but their significance is unclear. Immunoresponse was not altered, nor was there a noted increase in susceptibility to infectious diseases. At present, a NIEHS/IARC group is conducting a epidemiologic survey of the 220,000 residents of the Seveso vicinity. Their preliminary findings confirm those stated above. No organs or body functions appear to be impaired, nor have spontaneous abortions and birth defects appeared to increase. These findings are, as yet, preliminary and studies of long-term effects, such as cancer, cannot be conclusive until a sufficient latency period has passed.

2.4.4 Carcinogenicity

Animal Studies. Four major long-term animal studies (Van Miller *et al*., 1977; Kociba, *et al*., 1978; Toth, *et al*., 1979; Huff *et al*., 1980) determined that 2,3,7,8-TCDD is carcinogenic in certain animal models. The Kociba study, in particular, provides substantial evidence that TCDD is a carcinogen in rats, a result confirmed by NCI's investigations.

A carcinogenesis study was conducted by Toth *et al*. (1979) in three groups of 48 male mice and an equal number of controls which were fed TCDD in doses of 0.001, 0.1 and 1.0 ug/kg/bw/day. Tumor incidence was significantly increased in the 0.1 ug/kg/bw group (48 percent) as compared to 18 percent incidence in the controls.

One of the most widely cited studies is that conducted by Kociba *et al*. (1978). By using an adequate sample size (50 male and 50 female Sprague-Dawley rats), Kociba overcame some of the methodological problems in earlier studies. As a result, his investigation is frequently utilized in health risk assessments. Over a two-year period, the rats were administered doses of 0, 0.001, 0.01, and 0.1 ug 2,3,7,8-TCDD/kg b.w./day. Effects associated with each dose are given in Table 2-11. No carcinogenic effects were noted at the lower dose levels. An independent pathology review by Squire confirmed Kociba's findings. (Squire, 1980).

As part of its carcinogenesis testing program, the National Cancer Institute (NCI) fed 50 male and 50 female Osborne-Mendel rats doses of TCDD in the amounts 0.0015, 0.0071, and 0.071 ug/kg b.w./day. Male rats exhibited a dose-related increase in follicular cell adenoma (thyroid) and an increased incidence of tissue fibromas. Female rats fed the high dosage showed increases in hepatocellular carcinoma, neoplastic nodules, subcutaneous fibromas, and adrenal cortical adenomas. These results confirm Kociba's findings in all but one respect. Kociba observed a significant tumorigenic response at a slightly lower dosage (0.01 ug/kg b.w. as opposed to 0.07 ug/kg b.w.).

The studies discussed above indicate that rats and mice exposed to 2,3,7,8-TCDD develop an increased incidence of cancers, particularly those of the liver. Most of the data indicate no tumorigenic response at levels below 0.01 ug/kg-b.w./day. The exception is Van Miller et. al who noted a tumorigenic effect at these lower doses.

Human Epidemiology. As with non-carcinogenic chronic effects, most data regarding human carcinogenesis pertains to occupational exposures during the use and manufacture of PCDD-contaminated materials. Several studies suggest a link between exposure to phenoxy herbicides and the induction of soft tissue sarcomas, a rare tumor type affecting the connective and other soft tissues. Hardell (1977) observed a total of seven patients with soft tissue sarcomas. Each patient had an occupational history involving exposure to phenoxy herbicides ten to 20 years earlier. A subsequent case control study indicated that persons in occupations involving exposure to phenoxy herbicides (i.e., 2,4-D and 2,4,5-T) had a higher relative risk of developing this type of cancer. Although questions have been raised concerning aspects of Hardell's methodology (e.g., use of questionnaires based on subject recall), the clustering of the sarcomas has raised considerable concern. Another study (Smith et al., 1983;) of New Zealand herbicide sprayers did not indicate a relationship between exposure of these materials and soft-tissue sarcomas.

TABLE 2-11

TOTAL AND INDIVIDUAL TUMORS IN MALE AND FEMALE RATS OF SIGNIFICANTLY DIFFERENT INCIDENCE THAN NON-TREATED CONTROL RATS (AFTER KOCIBA ET. AL. 1978)

Tumor or Tumor-Like	Dose Level (ug 2,3,7,8-TCDD.kg.bw^{-1}/d^{-1}							
Lesion	-0^{a}		0.001^{B}		0.01^{B}		0.1^{B}	
	M	F	M	F	M	F	M	F
Hepatocellular hyperplastic nodules	6	8	0	3	3	18^{y}	2	23^{y}
Hepatocellular carcinoma	2	1	0	0	0	2	1	11^{y}
Stratified squamous cell carcinoma of hard palate or nasal turbinates	0	0	0	0	0	1	7^{y}	4^{y}
Keratinizing squamous cell carcinoma of lung	0	0	0	0	0	0	7^{y}	1^{y}
Benign tumor of uterus	-	28	-	12	-	11	-	7^{s}
Benign neoplasm of mammary gland	-	73	-	35	-	36	-	24^{s}
Mammary carcinoma	-	8	-	4	-	4	0	0^{s}
Pituitary adenoma	26	43	6	18	11	13	13	12^{s}
Subcutaneous carcinoma	10	1	1^{s}	1	5	0	6	0
Acinar adenoma of pancreas	14	0	7	1	5	0	2^{s}	1
Adenoma of adrenal cortex	0	9	0	6	2	2	5^{y}	5
Pheochromacytoma of adrenal	28	7	6	3	10	1	4^{s}	2

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[a] Total (sex and group) 85 animals.

[B] Total (sex and group) 50 animals.

[y] Statistically greater than control data when analyzed using the Fischer exact probability test, p 0.05.

[s] Statistically less than control data when analyzed using the Fischer exact probability test, p 0.05.

Source: National Research Council of Canada, 1981

Zack and Suskind (1980) also reported one soft-tissue sarcoma death in their study of the Nitro explosion. Other studies which observed soft-tissue sarcomas possibly related to exposure to TCDD-contaminated materials are Moses and Selikoff (1981), Johnson, et al. (1981), and Sarma and Jacop (1981).

The other forms of cancer possibly associated with exposure to TCDD-contaminated materials include: non-Hodgekins lymphomas (Bishop and Jones, 1982); Olsson and Brandt, 1982), and Hodgkins and non-Hodgkins lymphomas (Hardell, 1979), stomach cancers (Axelson, et al., 1980; Thiess and Frentzel-Beyme, 1977). These results are contradicted by studies which do not show increased stomach cancer mortality rates (Riihimaki et al., 1978; Zack and Suskind, 1980; Cook et al., 1980; and Ott et al., 1980). Another study by Riihimaki et al. (1983) failed to detect a relationship between exposure to chlorinated phenoxyacids and increased overall cancer risks. However, the authors expressed reservations regarding the ten-year latency period as being adequate to allow a true assessment of these exposure risks.

Taken as a whole, the evidence for the human carcinogenicity of TCDD is not as substantive as that for animal models. The problems inherent in these investigations mirror those encountered in any environmental epidemiology: lack of data regarding the etiology of the specific cancer, the validity of self-administered questionnaires, the presence of confounding factors (e.g., occupation, other chemical exposures), estimation of exposure levels, and the lack of information on the latency period of that cancer. However, it is generally agreed that the Swedish case-control studies are suggestive of an association between soft-tissue sarcomas and long-term occupational exposure to phenoxy acids and chorophenols contaminated with dioxin.

2.4.5 Teratogenesis and Other Reproductive Effects

High doses of 2,4,5-T containing 0.1 ppm of TCDD are embryotoxic and produce cleft palate in mice (Moore, 1978). Kociba (1976) also noted reduced fertility and survival of the young at doses of 0.01 and 0.1 ug/kg/day in Sprague-Dawley rats. Experiments on rhesus monkeys, using relatively low doses, do not show similar effects, suggesting that the teratogenic potential of TCDD may be a species-specific phenomenon (Dougherty, et al., 1975).

Several studies have investigated the potential for teratogenic and reproductive effects in humans. Two independent surveys of South Vietnamese hospital records (Cutting et al. 1970, Meselson et al. 1971) did not reveal any marked increase in birth defects. A National Academy of Sciences committee which also examined medical records did not observe a conclusive relationship between exposure to herbicide (i.e., Agent Orange) and birth defects. They did, however, assert that the available birth records were not adequate to permit definite conclusions.

A reportedly high incidence of miscarriages was observed among a small group of women living in Alsea, Oregon. One of the two studies conducted by EPA showed a statistically significant relationship between the spraying of 2,4,5-T and the incidence of miscarriages. The study was later discredited due to a number of methodological problems including lack of proper controls and inadequate data regarding both the spraying and the usual incidence of miscarriages.

2.4.6 Mutagenicity

Hussain, et al. (1972) observed a high frequency of reversion to streptomycin independence (a reverse mutation) in Escherichia coli (Sd-4) following exposure to 2 ug 2,3,7,8-T_4CDD.mL^{-1} of incubation medium. 2,3,7,8-T_4CDD also produced reverse mutations at the histidine locus of Salmonella typhimurium (strain TA1532) but no mutagenic effects were observed using S. typhimurium (strain TA1530) (Hussain, et al., 1972). Since the 2,3,7,8-T_4CDD used in these studies was reportedly 99 percent pure, it was unlikely that the positive mutagenic responses were due to impurities in the test material.

Seiler (1973) assessed the mutagenicity of 2,3,7,8-T_4CDD in several strains of S. typhimurium without metabolic activation. Positive mutagenic responses were reported in strain TA1532, questionable responses in strains TA1531 and TA1534 and negative responses in strains GA6 and TA1530.

More recent studies with S. typhimurium (strain TA1532) (with and without metabolic activation) indicate that 2,3,7,8-T_4DD is not mutagenic (Nebert, et al., 1976; Wassom, et al., 1977; Mercier, et al., 1978). Negative mutagenic effects have also been reported in other strains of S. typhimurium, including TA1535, TA1537 and TA1538, tested with 2,3,7,8-T_4CDD (Nebert, et al., 1976; Wassom, et al., 1977, 1978; Mercier, et al., 1978).

Except for the early results obtained by Hussain, et. al. (1972) and Seiler (1973) using S. typhimurium (strain TA1532), the available data on the mutagenicity of 2,3,7,8-T_4CDD indicate that this compound is not mutagenic. The discrepancy in results for strain TA1532 could be attributable to the solubility of the 2,3,7,8-T_4CDD sample, its purity, different treatment protocols or differences in the test organism (Wassom, et al., 1977, 1978). There is very little data regarding mutagenicity in humans. Chromosomal analysis of plant workers exposed during the Seveso incident did not reveal differences in the statistical norm for chromosome damage.

2.4.7 Mechanisms of Toxicity

Receptor-Mediated Toxicity. 2,3,7,8-TCDD is an example of a large class of halogenated hydrocarbons which appear to bind to a specific receptor (a soluble protein) within the cytoplasm of the cell. Once the TCDD and receptor are bound together, the dioxin-protein complex moves into the cell's nucleus where it activates a specific set of genes referred to as the Ah (aromatic hydrocarbon) locus. These genes control the production of cytochrome P-450, an enzyme which reacts with foreign substances in the cell. Although the primary function of cytochrome P-450 is electron transport, this enzyme also enables the toxic material to be metabolized and eventually excreted. In the case of dioxin, one of the metabolites triggered by cytochrome P-450 is toxic and manifests its presence as a toxic effect.

At present, the relationship between enzyme induction by TCDD and the degree of toxicity is unclear. In addition, as shown in Table 2-6, there is wide variability in AHH induction among the various PCDD isomers tested. Oral administration of TCDD in rats and mice produces a dose-related induction of AHH activity which seems to correspond with the toxic potency of specific dioxin cogeners. However, although TCDD is an extremely potent enzyme inducer in cell cultures, there is no demonstrated correlation between enzyme induction and cytotoxicity. This observation implies that despite the observed correlation in animal models, there may be no direct connection between enzyme induction and the degree of toxicity of 2,3,7,8-TCDD.

Vitamin A Depletion. Many of the toxic effects of 2,3,7,8-TCDD resemble the effects of Vitamin A (retinol) deficiency. These include epithelial lesions, keratosis and immunosuppressive effects. It has been demonstrated that the administration of a single oral dose of 2,3,7,8-TCDD produces a dose-related increase in the hepatic (liver) storage of Vitamin A in rats (Thunberg *et al*. 1979, 1980). These results suggest that an induced Vitamin A deficiency may be responsible for some of the toxic effects produced by 2,3,7,8-TCDD.

Lipid Peroxidation. Sweeney and Jones (1983) have suggested increased lipid peroxidation as a possible mechanism of 2,3,7,8-TCDD toxicity. Based on limited data, it appears that iron deficiency inhibits *in vitro* lipid peroxidation and reduces the hepatotoxic effects of 2,3,7,8-TCDD. Also lipofuscin pigments, by-products of lipid peroxidation, are increased in the heart muscle of rats treated with 2,3,7,8-TCDD. Thirdly, administration of an antioxidant to mice provided some protection from porphyria induced by 2,3,7,8-TCDD. More recent studies (Stohs *et al*., 1983) indicate that 2,3,7,8-TCDD may accelerate lipid peroxidation in Sprague-Dawley rats.

2.4.8 Summary. Relatively little is known regarding the effects of PCDDs and PCDFs on humans. Animal studies, which are limited primarily to 2,3,7,8-TCDD, indicate that this compound shows considerable variation in toxicity and varying effects among species, as well as a delay between the administration of this material and the manifestation of a toxic effect.

As regards humans, most information is derived from cases of accidental exposure to mixtures containing PCDDs. Assessing the effects of these uncontrolled exposures and relating effects solely to exposure to PCDDs is difficult. The symptoms observed in these incidents include skin conditions; hair loss and excess hair growth; nervous disorders; respiratory problems; liver, kidney, and gastrointestinal conditions; and hypothyroidism. The symptom most frequently associated with exposure to PCDDs is chloracne.

2,3,7,8-TCDD has been proven carcinogenic in several animal models. With one exception, these studies do not indicate tumor formation at levels below 0.01 ug/kg-b.w./day. There is some indication of a relationship between exposure to phenoxy herbicides and the development of certain cancers, notably soft-tissue sarcomas in humans. Other studies, however, seem to contradict these findings. In general, evidence for human carcinogenic effects is not as substantive as that for animal models.

Although teratogenesis and other reproductive effects have been noted in mice and rats, studies conducted to date of human populations have not shown a significant increased risk of spontaneous abortions and birth defects.

Available data on the mutagenicity of 2,3,7,8-TCDD seem to indicate that this compound is not mutagenic in the test systems used. Chromosomal analysis of plant workers exposed at Seveso did not reveal statistically significant increases in chromosome damage.

3. Dioxin Emissions from Incineration

3.1 Introduction

3.1.1 Purpose. This chapter presents an analysis of available data pertaining to the high-temperature behavior of PCDF and PCDD compounds. The data was derived from the sampling and analysis of municipal incinerator effluents and laboratory tests.. The results of this analysis will be used to predict PCDD and PCDF emission rates for the proposed Brooklyn Navy Yard Resource Recovery Facility (BNYRRF). These emission rates will then be used to develop the exposure assessment presented in Chapter 4 and the risk assessment presented in Chapter 5.

3.1.2 Approach. In order to predict behavior of PCDF and PCDD materials at high temperature, this analysis identifies the factors that influence their rates of formation and destruction. Laboratory studies which attempt to provide insight into these processes have been reviewed, and the information has been used to predict the impact of the BNYRRF emissions on the environment. Sampling and analysis data at other resource recovery facilities were reviewed in order to obtain the possible range and expected magnitude of emissions from the BNYRRF. Due to the lack of data, as well as to the differences in sampling techniques, incinerator design, and control equipment design in the reports from the various facilities tested, this is not a straightforward task.

The factors affecting high-temperature formation and destruction of PCDF and PCDD materials are correlated with actual test data in an attempt to identify factors influencing emission rates of these materials from incinerators. These factors are compared to the proposed design of the BNYRRF and emissions are predicted based upon test data from other facilities of similar design. Finally, an assessment is made based upon comparisons of data from other facilities, to determine if the emission prediction is a realistic one.

3.2 Factors That Influence Rates of Dioxin Emission

3.2.1 Formation (Occurrence). The PCDFs and PCDDs found in incinerator effluents are compounds that, once formed, are very stable and resist degradation. The exact formation and occurrence mechanisms are not thoroughly understood; however, an extensive examination of the data by researchers has led to the development of three theories to account for the presence of PCDF and PCDD compounds in the incineration effluent (Choudhry et al. 1980):

- the compounds are trace components of refuse and do not undergo thermal transformation;
- the compounds are produced from precursors such as PCBs, chlorophenols, and similar materials; and
- the compounds are formed de novo from materials that are unrelated to PCDF and PCDD compounds, such as PVC and other plastics, petroleum products, chlorocarbons, and inorganic chloride ions.

The first theory postulates that PCDF and PCDD materials are fed into the municipal incinerator with the raw refuse. Since PCDFs and PCDDs have been frequently formed as byproducts and contaminants of some chemical intermediates, (e.g. polychlorophenols, polychlorinated biphenyls, and hexachlorophene, and products made from these intermediates, such as herbicides, sanitizers, and heat transfer fluids), it is possible that some of these products can find their way into the solid waste of a municipal incinerator. Some researchers report that PCDD and PCDF compounds have occurred as contaminants in commercially available chlorinated phenols in concentrations up to 1,380 ppm for octa-CDD in pentachlorophenol (Rappe et al. 1979).

Most studies have not detected PCDF and PCDD materials in raw municipal solid waste (Lustenhouwer et al. 1980). However, in one recent study where three samples of raw waste were analyzed (Tosine et al. 1983), hepta-CDF and octa-CDD were detected. Concentrations ranged from 0.4 to 0.6 ng/g for octa-CDD and from 0.1 to 1.0 ng/g for hepta-CDF. Since municipal refuse is a highly variable and heterogeneous material, it is difficult to assess average concentrations of any component without taking a large number of representative samples. The Tosine study, however, shows that it is possible for some PCDF and PCDD materials to find their way into refuse. Since the discovery of PCDF and PCDD contaminants in certain products and intermediates, manufacturing controls have improved and contamination rates have decreased. Therefore, the incidence of PCDF and PCDD in refuse may decrease in the future.

In order for the quantity of hepta-CDF and octa-CDD found in the Tosine study to result in the low concentrations observed in municipal incinerator emissions, it would have to pass through the entire combustion system unchanged. As will be shown in this section, laboratory studies have shown that the flame temperatures found in municipal incinerators are capable of destroying 99 percent or more of these materials. Therefore, unless the incinerator combustion conditions are radically different than these laboratory studies, it is not likely that this is the primary source of PCDF and PCDD in incinerator emissions.

The second theory, which involves thermal transformation of PCDF and PCDD precursors, could account for formation of these materials in the combustion system. If the precursors, which are generally the materials described above as having PCDF and PCDD materials as contaminants, are heated to decomposition temperatures, but not heated to combustion temperatures, PCDFs and PCDDs can be formed. In addition, volatilization of those PCDF and PCDD contaminants in the precursors can also occur.

Swiss and Swedish researchers (Jansson et al. 1978) found PCDD compounds in the emissions from a laboratory combustor when wood chips treated with tri-, tetra,- and penta-chlorophenol were burned. The researchers found amounts of PCDD up to several hundred ppm on the fly ash when the incinerator operated with tri- and tetra-chlorophenol treated wood chips in the temperature range of 500-600°C. Above 750°C the emissions of PCDD were very low. (However, as described below, pyrolysis of lignin from virgin wood can form PCDF and PCDD when exposed to chlorine in the combustion process. This demonstrates that the precursors in this study may not have been the source of the PCDF and PCDD materials detected).

Combustion of grass and paper coated with the herbicide 2,4,5-trichlorophenoxyacetic acid (2,4,5-T) at 600-800°C generated traces of TCDD materials in the ppm range (Stehl and Lamparski 1977). Since 2,4,5-T has been found to contain TCDD as a contaminant, the 2,4,5-T can contain TCDD precursors. However, it is not clear whether the TCDD materials were formed from the precursors or from a combination of chlorine and other decomposition products resulting from the combustion process.

Polychlorinated biphenyl (PCB) heat transfer fluid has been found to convert to PCDF compounds during transformer fires and explosions when the PCB was exposed to relatively low temperatures and restricted oxygen conditions (Rappe et al. 1979, 1982). Since no other materials were combusted during these episodes, it is clear that the source of PCDF materials was indeed the fire/explosion of PCB. It is apparent through laboratory studies that the pyrolysis and combustion of PCDF and PCDD precursors can result in emissions of these materials. There are, however, no studies that have shown that this occurs in full-scale incinerators. Obviously, the conditions found in the laboratory studies would have to be reproduced in a full-scale unit. As described in Section 3.3, there is a wide range of combustion conditions found in full-scale units, depending upon both design and operation of the incinerator. These conditions can profoundly affect the concentrations of PCDF and PCDD materials in the emissions.

The third theory for the occurrence of PCDFs and PCDDs in municipal incinerator emissions suggests that these materials are formed from unrelated materials under specific conditions. Pyrolysis of uncontaminated pure vegetable extracts (from wood) in a laboratory combustor has yielded phenolic compounds which, when exposed to chlorine, resulted in ppm-range PCDF and PCDD emissions (Liberti et al. 1983). These researchers have postulated that degradation products which react with chlorine are the result of pyrolysis of the lignin binder from the wood extracts. Since chlorine is obviously a necessary component in the formation reactions under this theory, the source of chlorine in a typical municipal incinerator is an important topic. Generally, organic chlorine makes up one-half or more of the total chlorine in solid waste, with the remainder being inorganic salts

(Freeman 1978, Velzy 1984). Until a few years ago it was felt that chloride salts did not break down in incinerators; it was felt that the salts remained in the bottom ash (Freeman 1978). However, recent research in Japan has revealed that virtually all chlorine from salt can be liberated to form hydrogen chloride if the salt is exposed under heat to other components typically found in solid waste (Uchida et al. 1982). These components are silica (sand) and alumina (aluminum oxide). It is also known that reactions between gaseous sulfur dioxide and salt under heat can yield sodium sulfate and hydrogen chloride (Uchida et al. 1982). Therefore, chlorine in any form in solid waste can potentially contribute to the formation of PCDDs and PCDFs in incinerators under the right conditions.

Another interesting study concerning chlorine in solid waste is one where polyvinyl chloride (PVC) was added to the raw waste of a full-scale Martin incinerator in proportions of 5.33 kg per ton of waste (a 300 per cent increase over normal levels) and fly-ash samples were taken. The authors state that there were no significant increases in PCDF/PCDD concentrations over emission levels without added PVC in the waste (Karasek et al. 1983). Although PVC is not a PCDF and PCDD precursor, PVC has been reported as a potential source of chlorine for the formation of PCDDs and PCDFs (Liberti et al. 1983). However, at least in the incinerator tested, this did not occur.

Another study which adds insight to this formation theory is one reported by Olie et al. (1983), where hexachlorobenzene was added to the fuel of a municipal incinerator in proportions of 400 g to 2 m^3 of raw waste, while fly-ash samples were taken. Chlorobenzenes are known precursors of PCDFs and PCDDs (Lustenhouwer et al. 1980); however, there was no significant increase in PCDF or PCDD concentrations emitted with the fly ash when the hexachlorobenzene was added. This indicates that waste input composition is probably not the single most significant cause of PCDF and PCDD emissions from municipal incinerators.

Experiments were also performed with a small fluid-bed incinerator by burning wood that was treated with pentachlorophenol preservative (a known PCDF/PCDD precursor) and 60-year old painted wood that was not treated with preservatives. There were no significant increases in PCDF/PCDD levels on the fly ash from the treated wood over the levels from the untreated wood (Olie et al. 1983). Furthermore, paper treated with a hypochlorite solution was burned and only traces of PCDF and PCDD compounds were emitted. The authors even state that the traces could have occurred as artifacts of the previous tests with wood burning. These experiments indicate that the occurrence of PCDF/PCDD emissions from municipal incinerators is not necessarily a direct result of a limited number of specific compounds in the raw solid waste, since the addition of known precursors did not necessarily cause higher emissions.

Also, studies on residential wood combustors (Nestrick and Lamparski 1983) showed that even when burning untreated virgin wood, PCDD materials at the part-per-trillion level could be detected in the soot and ash. This indicates that even trace amounts of chlorine from soil, air, construction materials, etc. can contribute to the formation of PCDDs and PCDFs.

These results show that PCDF and PCDD materials may occur in incinerator effluents by one or more mechanisms. It is important to remember, however, that laboratory and pilot-scale studies do not necessarily reflect conditions in a full-scale modern municipal combustion system. The specific conditions prevailing during PCDF and PCDD formation in a full-scale combustion system are difficult to measure and little is known about the components and kinetics of reactions within these systems. But while information is incomplete regarding the formation of PCDFs and PCDDs, some information is known about conditions necessary for their destruction. This information is discussed in the following sections.

3.2.2 <u>Destruction</u>. Since the discovery of PCDFs and PCDDs as environmental contaminants, researchers have been investigating the physical, chemical, and toxicological properties of these contaminants. As described above, the reaction processes involved in the formation of this group of compounds are not precisely known. Once formed, it is very clear that these materials have an extremely high degree of thermal stability. This means that they retain their chemical structure at thermal conditions up to temperatures that are quite high. As more knowledge is becoming available concerning the conditions necessary for the thermal destruction of PCDFs and PCDDs, however, it is clear that these materials can be destroyed by the conditions present in a resource recovery plant.

This section contains a discussion of available information concerning conditions necessary for the destruction of PCDFs and PCDDs. A USEPA report on high-temperature destruction (Duvall and Rubey, 1977) estimates 99 percent destruction for dibenzodioxin and dibenzofuran materials at 700°C, and 99.9 percent destructon at 725°C (assuming one second residence time and effective mixing). However, these values are for monochlorinated materials and the thermal stability may increase with the number of chlorine substitutes. Therefore, the higher chlorinated materials such as the tetra, penta, hexa, hepta, and octa forms, may require higher temperatures for destruction. The study also reported that at 704°C the residence time necessary to destroy PCDD and PCDF could range from one to four seconds, with higher residence times necessary for the higher chlorine substitutes (assuming effective mixing).

Researchers conducting studies on 2,3,7,8 tetra-CDD (Bumb et al., 1980) determined that 99.95 percent of this material decomposes above 800°C, while at lower temperatures it is relatively stable (i.e., does not burn easily). Calculations based on reaction kinetics have also been performed; the researcher has estimated that 99.99 percent of all forms of PCDDs can be destroyed at a combustion temperature of 957°C and a gas residence time of one second. (Schaub and Tsang, 1981). This is very close to the design temperature (980°C) of the BNYRRF furnace zone. A summary of these destruction parameters is shown in Table 3-1.

It must be noted that these are the results of theoretical analyses or laboratory studies where temperatures, air supply, air/fuel mixing, and residence time are much more closely controlled than would be the case in an incinerator burning heterogeneous waste. Therefore, these estimates can

TABLE 3-1

ESTIMATED OR MEASURED DESTRUCTION EFFICIENCIES FOR PCDF AND PCDD COMPOUNDS

Compound	Destruction Efficiency(%)	Destruction Temperature(°C)	Conditions
dibenzodioxin/dibenzofuran (a)	99	700	perfect mixing, one second residence time
dibenzodioxin/dibenzofuran (a)	99.9	725	perfect mixing, one second residence time
2,3,7,8 TCDD (b)	99.95	800	laboratory combustor
PCDD (c)	99.99	957	reaction kinetics of typical combustion system, one second residence time
chlorinated compounds (d)	minimum emissions	800	well-mixed, one to three seconds residence time

(a) Duvall and Rubey, 1977 (higher chlorinated isomers of CDDs and CDFs will require higher destruction temperatures)

(b) Bumb _et al_., 1980

(c) Schaub and Tsang 1981

(d) CARB 1983

only be used as guidelines, since high temperature in an incinerator does not always coincide with optimum air supply, air/fuel mixing, and residence time. The following discussion pertains to actual incinerators and the requirements for effective PCDF and PCDD destruction in full scale units.

The California Air Resources Board (CARB) suggests that effective destruction of chlorinated compounds can occur at temperatures of 800°C at residence times of one to three seconds, under extremely well-mixed conditions (CARB, 1984). Properly designed and operated incineration facilities can achieve maximum flame temperatures in excess of 1300°C with average combustion chamber temperatures of 980°C and residence times greater than one second (CARB 1984). This report also states that these conditions can be expected to result in minimum emissions of PCDFs and PCDDs. It is probable that neither zero formation nor complete destruction of PCDF and PCDD emissions will occur in any municipal incinerator, although studies of coal/solid waste combustion emissions have resulted in no detectable PCDF and PCDD emissions (Redford et al. 1981).

It is apparent that, if these PCDFs and PCDDs are formed from solid waste degradation products, as the third formation theory of Section 3.2.1 postulates, they can be thermally destroyed upon exposure to the proper combination of combustion conditions. Degradation products are generally formed in all incinerators at the fuel bed because underfire air flow is purposely kept low, causing starved-air conditions in order to drive off volatiles without entraining solid unburned particles. The difference in rates of PCDF and PCDD emissions per ton of solid waste from different incinerators is primarily caused by combustion conditions downstream of the fuel bed. The downstream or secondary combustion zone is where effective incinerators are designed to destroy these materials. Incinerators can be designed to promote maximum PCDF and PCDD destruction by controlling the amount and injection method of secondary combustion air supply, the temperature and length of time the combustible gases remain at the minimum combustion temperature, and the effectiveness of the secondary air in mixing with the fuel gases. The goal for minimum PCDF and PCDD emissions is to keep the air/fuel mixture just slightly oxygen-rich at all times in order to burn the fuel completely at the hottest temperature within the design limits.

Regardless of the source and amount of PCDF and PCDD in the combustion system, maintenance of these secondary combustion conditions will ensure minimum emissions.

In addition to incinerator design factors, the method of operation will affect the ability to destroy PCDFs and PCDDs. For example, if too much fuel is charged to the combustion chamber and not enough air is supplied (fuel-rich mixture) the oxygen content of the gas will go down and carbon monoxide content will go up. This will require adjustments in the charging rate, the air supply, or both. Too much air supply will result in an oxygen-rich mixture, causing flame chilling and subsequent temperature drop. Obviously, in order to control the combustion process it is imperative that the operator of an incinerator know at all times exactly how much oxygen and carbon monoxide are in the furnace gases and at what temperature the combustibles are burning. Therefore, an effective incinerator design would include reliable instruments for measuring these parameters with displays in an area easily seen by the operator at all times. Failure to control the combustion process using these measurements will result in PCDF and PCDD emissions significantly higher than the minimum rates.

3.3 Emission Test Data from Municipal Waste Incineration

Beginning in the mid-to-late 1970s, it was reported by European researchers (Olie et al. 1977) that PCDDs and PCDFs were detected, but not quantified, in the fly ash collected in electrostatic precipitators in several of the Netherlands municipal incinerators. Other researchers also quantified trace levels of PCDDs and PCDFs in the collected fly ash (Buser and Bosshardt 1978, as reported by Lustenhouwer et al. 1980) of a municipal incinerator. In the Buser study, tests in the high-temperature zone of the boiler gas passage indicated low levels of only the octa-CDDs on the fly ash, while simultaneous samples at the lower-temperature electrostatic precipitator fly ash hoppers showed significant levels of all PCDFs and PCDDs from tetra- through octa- on the fly ash.

As the sensitive analytic techniques necessary to detect these compounds in trace quantities were developing, actual concentrations of PCDDs and PCDFs in fly ash were determined by other researchers in the ng/g range (Bumb et al. 1980; Eiceman et al. 1979; Lustenhouwer et al. 1980). It became apparent that municipal solid waste incineration could be a potentially significant source of tetra-CDD emissions when the quantities of emissions from the Hempstead, Long Island, resource recovery facility were determined in 1979 (Tiernan et al. 1982). About this time, the emission data from Italian incinerators were made public (Cavallaro et al. 1980), showing that PCDFs and PCDDs may apparently be present in both the adsorbed state (on particulate) and the vapor phase. This apparently supported the Buser data, where PCDF and PCDD materials were not found on the fly ash in the high-temperature combustion zone but were subsequently found on particulate fly ash as the temperature decreased. There is also the possibility, however, that in the Buser study the PCDF and PCDD materials were adsorbed on particulates in the hot zone but were thermally desorbed when drawing hot sample gas past the particulates collected on the filter medium.

The sampling method used to obtain fly-ash samples from flue gas streams consists of drawing a sample of gas from a stack through a nozzle and probe before filtering the fly ash from the sample gas. The entire system from nozzle to filter is kept at an elevated temperature, typically 120° C to 250° C for stack gases, or higher for a very hot gas stream. After passing through the filter, the sample stream is typically cooled to below ambient temperature so that moisture is condensed and collected to prevent damage to sensitive pumps and meters downstream of the filter. Condensible moisture will readily drop out of the stream, but only a small portion of the organic material will be removed. The remainder passes through the sample train as a gas or a very small-size aerosol. Typically, after a volumetric measurement, the condensed water is discarded. All the researchers mentioned above, except Cavallaro and Tiernan, use this method to obtain flue gas fly ash samples.

Modern refinements to the sampling system have been made in recent years to trap the portion of PCDDs and PCDFs that would previously have been collected in the condenser or would have passed through the train. The USEPA has developed and tested a method which collects the gaseous and condensible organics in a specially-cooled condensate trap between the heated filter and the moisture condenser. This trap collects the condensed organics on polymer resin beads, which are then extracted with a solvent prior to analysis. This method can collect condensibles and gases that escaped the older method. Only this method, or one similarly designed to collect gaseous material as well as fly ash, should be used to assess total PCDD and PCDF emissions from incinerators.

However, the partition factor between the amount of gaseous PCDF/PCDD and the amount on fly ash is very strongly linked to the temperature profile and residence time in the sampler. Therefore, small changes in sample flow rate, temperature, or dimensions of the hand-blown glassware in the sample train can change the partition factor. For this reason, some researchers, including the USEPA, refuse to report the partition of PCDF and PCDD emission as gaseous or as fly ash. In accordance with this position, there will be no attempt in this report to presume that PCDF/PCDD emissions are in any particular proportion between gaseous and solid state. Only samples where both solid and gaseous forms were obtained are used to develop predicted emission rates, and only total gaseous-plus-fly-ash emission rates and/or concentrations form the predicted emissions for the BNYRRF.

Data has been published by both European and United States researchers showing that PCDFs and PCDDs can be emitted from municipal waste combustion systems in amounts ranging from very low levels to potentially significant levels. As described in Section 3.2, significant emissions can potentially occur during periods of poor combustion, e.g. insufficient combustion air or low combustion temperatures. Also, potentially significant emissions could occur if the incinerator is designed with low gas residence time and is subsequently overcharged or operated with a different type of waste than the waste for which it was designed. Unfortunately, the combustion conditions are frequently not thoroughly described when emission data is reported. This prevents a thorough comparative analysis of each test report.

One study on one incinerator over a long-time period (Benfenati et al. 1983) showed an inverse relationship between minimum combustion temperatures observed during sampling and both PCDF and PCDD emissions. Obviously, with a complex combustion facility, this could only occur when all other combustion parameters, such as excess air and degree of air/fuel mixing, remain within the desired ranges. Another study on an incinerator in the Netherlands over a long period of time (Olie et al. 1980) reported average combustion temperatures and PCDD/PCDF emissions. The difference between average and minimum combustion temperature may be a significant factor in the different results from these two studies. It is more likely, however, that factors other than temperature, such as availability of combustion air, air/fuel mixing, gas residence time, or a complex combination of factors that were not monitored, were responsible for the variation. This comparison of contrasting results indicates the extreme importance of combustion monitoring and close control of combustion conditions. Slow operator response to temperature excursions and poor control of the air/fuel mixture may potentially result in significant increases in PCDF and PCDD emissions.

Virtually all available PCDF and PCDD emission data from municipal incinerators, where both gaseous and solid (i.e., adsorbed onto particulate fly ash) components are included in the results, are compiled from published literature and presented in Appendix A. Most data where stack fly ash only was measured, or where fly ash collected in the precipitator was measured, are not included in this compilation.

The results of some studies have been converted in order to present the data in common units. Since most of the data is reported by European researchers, the results are presented in units commonly used by the Europeans (i.e. ng/m^3 normalized to 0°C and 1 atmosphere pressure). Where data is available concerning the separation of the gaseous and solid phases, it is reported as total PCDF and PCDD emissions. Since the partition factor between the gaseous and solid phase is temperature-dependent and the sampling method significantly changes the temperature characteristics from the characteristics that occur when the emissions traverse the system, the gaseous and solid partition cannot be representative.

Some data is presented which includes analyses of the solid phase only. Since the results are averaged from a large number of samples, the data is statistically representative even though it is not ideal for predicting emissions. If these samples were taken from a system where all condensation and adsorption had occurred prior to the sampling point, then these data are representative of total emissions. Since it is impossible to tell if this occurred in the test systems, this data is presented for comparison purposes only. All facilities tested were equipped with electrostatic precipitator air pollution control equipment for particulate collection and samples were taken downstream of the collectors.

Since the incinerator design and operation characteristics can affect the magnitude of PCDD and PCDF emissions from municipal waste combustors, it is important to identify the type of combustion system and the prevailing operating conditions during the tests. Unfortunately, this data is often lacking when emission test results are published. Therefore, much of the data is not suitable for use in predicting emissions from the BNYRRF. However, some data has been taken from incinerators similar to the one proposed for the Brooklyn Navy Yard and this data is considered the most suitable in assessing the BNYRRF emissions.

A certain amount of information has been collected concerning incinerator types and operating conditions at the facilities tested. The Chicago Northwest facility is a Martin combustion system that had been in operation about nine years when it was tested; and the Zurich-Josephstrasse combustor is also a Martin design. Both of these systems are similar in design, operation, and waste type to the proposed Brooklyn Navy Yard Facility. Both were also sampled for gaseous and solid PCDD and PCDF components and the results presented reflect total emissions.

The Como, Italy, incinerator is a relatively simple refractory-lined unit that generates a small amount of steam for in-plant use. This facility was sampled for condensible solid and liquid effluents. The Hampton, Virginia plant is a refuse-fired steam boiler that was found to be firing refuse above its efficient capacity and at relatively low temperatures during testing by the USEPA. The owners of the Hampton plant have been requested by USEPA to revise their operating conditions in order to reduce the PCDF and PCDD emissions, and the facility is due to be re-tested. Clearly, the emissions from this incinerator are not representative of normal emissions under generally acceptable operating conditions. However, this facility was sampled for both particulate and gaseous forms of PCDFs and PCDDs, and the data reflects total emissions. The two plants in Milan, Italy, are resource recovery steam plants with Volund combustion systems. The Eskjo, Sweden, plant is a refuse-fired fluidized-bed boiler operating at 700°C and two seconds gas retention time. Both gaseous and condensible forms of PCDFs and PCDDs were measured at these Italian plants and at the Sweden plant. The Zaanstad, Netherlands plant is a simple refractory-lined furnace. The effluent was sampled and analyzed for solid PCDD and PCDF forms only. Of these systems the Chicago Northwest facility and the Zurich-Josefstrasse facility are the closest in design and operation to the BNYRRF. In addition, these facilities were sampled using methodology which includes gaseous and solid forms of PCDFs and PCDDs. Of note, the emissions from these facilities are among the lowest of all those tested. The highest values were obtained from incinerators about which absolutely no information was presented regarding furnace combustion conditions during testing.

3.4 Factors Affecting Rates of Dioxin Emissions from Incinerators

From Section 3.2 it is clear that a complex set of circumstances influence the rate of PCDF and PCDD materials in incinerator effluents. The results of the laboratory studies indicate that the primary method of achieving minimum emissions is a maximization of combustion efficiency. That is, with combustion temperatures of about 900°C, the air/fuel mixture must be just slightly oxygen-rich, the mixture must be homogeneous (no stratification), and the gas residence time at the average combustion temperature must be at least one second. These conditions are not extreme; they are attainable with fully developed and tested technology. This is demonstrated by the emission data obtained from the Chicago Northwest facility (Redford et al., 1981) and the Zurich-Josefstrasse facility (SFOEP, 1982).

The system central to these facilities, the Martin stoker-grate, has been developed over many years with the goal of promoting optimum combustion efficiency.

In contrast, many other incinerators were designed with the primary goal of reducing waste volume. It is cheaper and easier to design and build an incinerator that effectively reduces waste volume without providing a high combustion efficiency. These facilities do not have the high-velocity secondary air nozzles to provide air/fuel mixing, or the larger dimensions to provide long gas residence times, or the sophisticated control systems necessary to keep conditions from exceeding their desired ranges. Two relatively simple incinerators without resource recovery are the Como, Italy and the Zaanstad, Netherlands facility. Emissions from these plants are one to two orders of magnitude greater than the Chicago, Northwest facility.

However, a resource recovery design in itself does not assure that PCDF and PCDD emissions will be minimal. Three systems that were designed for resource recovery emitted relatively high PCDF and PCDD emissions. These are the two plants in Milan, Italy (Cavallaro et al. 1980) with Volund steam generation systems and the Hampton, Virginia refuse-fired steam boiler (Tiernan et al. 1983). Emissions from these systems are two to three orders of magnitude higher than the Chicago, Northwest facility emissions. Six Italian plants were tested but the types of incinerators were not described (Cavallaro et al. 1982). The concentrations of PCDF and PCDD ranged several orders of magnitude from moderate (10-20 ng/Nm^3 TCDD) to very high levels (38,635 ng/Nm^3 HCDD).

The extreme range of emissions shown in these studies demonstrates that the factors influencing PCDF and PCDD emissions are complex. Although design can play a significant role in the magnitude of emissions, it is not probable that design alone can assure low emissions. The most probable cause of the wide range of emissions is flucuations in operating conditions from plant to plant and from day to day. This shows that the most important factors of any incinerator operating plan are the operating procedures, knowledgeable operating personnel, and well-maintained equipment. It is encouraging that a design similar to the BNYRRF proposal, the Chicago, Northwest facility, has the lowest PCDF and PCDD emissions of all those tested, and that it was tested after nine years of operation. This clearly demonstrates that an effective design can be combined with good operations to minimize PCDF and PCDD emissions.

3.5 Brooklyn Navy Yard Facility Design

The proposed 3,000 ton per day (tpd) Brooklyn Navy Yard resource recovery facility is to be developed under a full-service contractual arrangement, including 20 years of commercial operation by the contractor. The proposed processing system will include four 750 tpd combustion units, and each unit will consist of an individual combustion chamber, boiler, air pollution control device, and ash-handling equipment. The four units will share one 500-foot stack equipped with four flues.

The proposed facility will incorporate the Martin stoker system, a mass-burn technology similar to that currently employed at three facilities in the United States and many more throughout the world, including comparably-sized units in Europe and Japan. The U.S. facilities which are currently in operation are the Northwest Waste-to-Energy Facility in Chicago, the City of Harrisburg, Pennsylvania's, Resource Recovery Facility, and the Pinnellas County, Florida Resource Recovery Facility. The Florida facility is currently being enlarged to 3,000 tpd capacity. All three facilities incorporate a furnace stoker mechanism (a critical component in mass-burning) which is the same as that proposed for the Brooklyn Navy Yard operation.

Combustion controls are an inherent part of the facility design. Certain design features of this system optimize combustion efficiency in order to maximize steam output, while minimizing pollutant formation. Underfire air jets and the reverse-reciprocating action of the Martin stoker-grate agitate the fuel bed continuously in a manner to cause refuse burning from the bottom of the refuse bed, thus resulting in an effective burnout rate. The grate is inclined downward, toward the discharge end, and consists of both fixed and moving rows of grate bars. The moving grate pushes upward against the natural gravitational movement of the refuse at 30 to 50 strokes per hour. This movement agitates the burning refuse in an attempt to form an even depth of fuel bed. Burning refuse is pushed back underneath the freshly fed refuse to achieve continuous drying, volatilization, ignition, and combustion.

The occurrence of hot-spots, which can generate excessive nitrogen oxides, and starved air spots, which can generate excessive carbon monoxide, is minimized by the action of the stoker-grate. In the combustion chamber, all smoldering and unburned gases from the discharge end are led back under the rear arch directly into the high-temperature combustion zone. This increases the residence time and enhances combustion of suspended combustible matter. At the furnace throat, where the high-intensity combustion takes place, closely spaced high-pressure overfire air jets on the front and rear furnace walls cause intense flame turbulence and prevent stratification of unburned gases, thus increasing the likelihood of complete combustion before passage into the boiler.

Continuous monitoring instrumentation for oxygen, carbon monoxide, and temperature of the furnace gases will be provided for instantaneous measurements. These instruments will supply information on the state of the combustion process and will give the operators the knowledge necessary to control the combustion for the most efficient operation.

In addition, natural gas auxiliary burners will be located at the point where secondary air will be injected, to maintain a minimum secondary combustion temperature at 980° C, even during startup and shutdown. This is a new application for auxiliary burners. Resource recovery plants in the past have not used auxiliary burners in this manner. The auxiliary burners will enable the plant to maintain residence time at design temperature even when burning wet solid waste. Combustion controls based upon temperature and flue gas composition will be used to operate the plant. Although not fully designed yet, these operating controls will probably include a combination of automatic and manual functions during operations. The selection of an efficient mass-burn technology with thermal combustion controls is consistent with current state-of-the-art technology.

The post-combustion particulate control equipment chosen for this facility is a high-efficiency (greater than 99.5 percent) fabric filter, designed to meet an outlet particulate emission loading of 0.015 gr/dscf at 12% CO_2. This particulate emission rate is well below the Federal New Source Performance Standard (40 CFR 60.52) and the New York State emission limitation (Part 222).

3.6 Predicted Emissions From Brooklyn Navy Yard Facility

In order to generate representative emissions for the BNYRRF, a set of data were developed from the available literature. In selecting the test data, the objective was to find similarity in design, operations, and waste type. Furthermore, test data obtained using sampling methods that are compatible with methods approved by USEPA for sampling organics in flue gases were considered desirable. Unfortunately, there are no test data which meet all these criteria. For example, there are no data on any incinerators which use auxiliary burners for secondary combustion control or fabric filters for particulate emission control.

The auxiliary burners are essentially a backup system for situations where the secondary combustion temperature falls below the design level. Therefore, no emissions data correction is required in order to account for the use of auxiliary burners. The use of fabric filters, on the other hand, requires some additional calculations from the test data in order to present a realistic picture of emissions, since fabric filters collect more particulate matter than the more commonly used electrostatic precipitators.

If the PCDF and PCDD materials are adsorbed onto particulate matter, more of these materials will be trapped in the fabric filter than in a comparably sized electrostatic precipitator. By utilizing particle-size data and an assumption that PCDF and PCDD materials are adsorbed onto fly ash in proportion to the available particle surface area, calculations are made concerning the amounts collected and emitted. Since the partition between gas and solid forms is not known, emissions are calculated in two ways: (1) assuming all PCDF and PCDD materials observed at the test facilities are gaseous, and (2) assuming all PCDF and PCDD emissions observed at the test facilities are particulate. If the emissions contain both gaseous and particulate PCDFs and PCDDs, then the emission rates will fall between these values.

After examining all PCDF and PCDD emission data available in the literature, the emission data selected as the most representative of the BNYRRF are the data from the Chicago, Northwest facility and the Zurich-Josefstrasse facility. Both of these facilities use a furnace design similar to that proposed for the BNYRRF. The Chicago Northwest facility is located in an environment similar to that of the Brooklyn Navy Yard, i.e., a large U.S. metropolitan area; therefore, the waste is more likely to be similar to New York City waste than is the European. Furthermore, the sampling of the Chicago, Northwest facility was performed under sponsorship of the USEPA, using sampling methods designed to capture both gaseous and particulate forms of PCDFs and PCDDs. In addition, stringent quality assurance controls were used in order to assure representativeness. The Zurich-Josefstrasse facility was tested by the Swiss counterpart to the USEPA. The sampling method included both gaseous and particulate PCDFs and PCDDs in the sample, although the method is different from the USEPA method. Sampling of both gaseous and solid forms of PCDFs and PCDDs is important to ensure that the emission data are complete. Therefore, the Chicago Northwest data is the first choice, while the Zurich-Josephstrasse data is the second choice. It would be desirable to obtain test data from more facilities; however, the specific type of data necessary for an assessment of this type is scarce.

The referenced emission data (Redford et al. 1981) includes tri-CDF and tri-CDD emissions (which were not analyzed by any other researcher), but does not include penta-CDF or penta-CDD emissions. In order to complete the PCDF and PCDD emission data, the Chicago Northwest data is supplemented by the Zurish-Josefstrasse data for penta-CDF and penta-CDD emissions. It should be noted that these emissions were obtained from resource recovery facilities that use electrostatic precipitators for fly ash collection. Therefore, this data is conservative in comparison to the BNYRRF with a fabric filter for particulate control, unless the PCDF and PCDD emissions measured at the facilities with electrostatic preicipitators were entirely gaseous, in which case they would pass through the BYNRRF's fabric filter without being collected. The fabric filter, however, will emit less than half the weight of fly ash emitted by a precipitator comparable in efficiency to those used on facilities mentioned above. Therefore, unless the PCDF and PCDD emission concentrations from the referenced test facilities are all gaseous, the PCDF and PCDD emission concentrations from the BNYRRF would be less than those observed at the test facilities:

These emissions, corrected for the size of the BNYRRF, are shown in Table 3-2 as concentrations in the flue gas and as mass rates per unit time. In order to arrive at these latter values, the projected flue gas emission rate of 9,990 Nm^3/min provided the quantification of carrier gas flow. This value was calculated from values presented in the Preliminary Draft Environmental Impact Statement (PDEIS) previously submitted to the New York City Department of Environmental Protection (NYCDEP). The emissions presented in Table 3-2 assume no more PCDF and PCDD collection in a fabric filter than that observed in an electrostatic precipitator.

The evidence shows that the conditions assumed for Table 3-2, (i.e., that all PCDF and PCDD emissions are gaseous) are not realistic. This was shown by Lustenhouwer et al. (1980); Eiceman et al. (1979); Karasek et al. (1983); Olie et al. (1980); and others when they sampled fly ash emissions and/or fly ash from electrostatic precipitators at incinerators, and extracted PCDFs and PCDDs from the fly ash particles up to several hundred nanograms per gram. These tests did not attempt to collect gaseous and condensible materials; therefore, at least some portion if not all of the PCDFs and PCDDs leaving an incinerator stack will be adsorbed on fly ash. A more realistic scenario than the assumption that all PCDDs and PCDFs are gaseous is that some PCDF and PCDD materials are adsorbed on fly ash and some are gaseous or adsorbed on ultra-fine particulates.

PCDF and PCDD compounds are volatile at temperatures well above ambient, but lower than those at which they would be destroyed. Once the compounds are cooled, they condense and, if particles are available, condense onto the particle surfaces (CARB, 1984; Kemp; 1983; ASME, 1981) . The materials would then be relatively stable compared to the volatility and adsorption/ desorption reactions occurring at elevated temperatures. One study (CARB, 1984) proposes that the finer particles, which have the greatest surface area, must be controlled as much as possible in order to minimize PCDF and PCDD emissions. This study also draws the parallel of heavy metals adsorption onto the fine particles and states that PCDF and PCDD materials behave similarly.

TABLE 3-2

PREDICTED PCDF AND PCDD EMISSIONS FROM BNYRRF (Assuming all PCDDs and PCDFs emitted are in gaseous form)

	Concentration in Flue Gas (ng/Nm^3)(c)	Mass Emission Rate (ug/sec)
Tri-CDF	307.4(a)	51.18
Tetra-CDF	92.2(a)	15.35
Penta-CDF	26.6(b)	4.43
Hexa-CDF	63.5(a)	10.58
Hepta-CDF	7.7(a)	1.28
Octa-CDF	0.6(a)	0.10
Total-CDF	498.0	82.92
Tri-CDD	13.3(a)	2.22
Tetra-CDD	6.5(a)	1.07
Penta-CDD	10.7(b)	1.79
Hexa-CDD	16.4(a)	2.73
Hepta-CDD	7.8(a)	1.30
Octa-CDD	2.6(a)	0.43
Total-CDD	57.3	9.54
2,3,7,8 Tetra-CDD	0.42	0.07

NOTES:

Nm^3 = Normalized cubic meters, 0°C and 1 atm pressure.

Flue gas flow rate = 166.5 Nm^3/sec

(a) Calculated from data published by Redford et al. 1981.
(b) Calculated from data published by SFOEP, 1982.
(c) Corrected to flue gas conditions projected for BNYRRF; i.e. 10.5% CO_2 (dry basis) and 13.63% H_2O.

This suggests that the PCDF and PCDD compounds are adsorbed on fly ash before entering the pollution control device. Since there is a design temperature difference between the pollution control device and the stack of the BNYRRF of only ten degrees, it is unlikely that condensation occurs in the stack. Therefore, if PCDF and PCDD materials are adsorbed before entering the pollution control device, some portion of these materials will be trapped in the fabric filter because the fabric filter is more efficient at collecting fly ash than the electrostatic precipitator.

There are a number of researchers who have reported higher concentrations of PCDDs and PCDFs emitted on fly ash from incinerator stacks than on fly ash collected in electrostatic precipitator hoppers. The increase in concentration has been reported to be from 2 to 12 times, depending upon the study, with 5 to 10 times being the most common range. Lustenhouwer et al. (1980) reports that stack fly ash emissions are significantly more concentrated than collected fly ash. Data presented in this study shows an average of 4.5 times more PCDF and PCDD on stack fly ash than on precipitator ash. Taylor et al. (1983) reports data from one test at the Hampton, Virginia municipal incinerator with an average of six times more PCDD and PCDF on stack fly ash than on precipitator ash. Ballschmitter (reported by Kemp 1983, CARB 1984, and Hutzinger 1984) reports that concentrations of TCDD on fly ash leaving an electrostatic precipitator in Hamburg, West Germany were 300 ng/g, while TCDD concentration on fly ash collected in the precipitator hoppers was 25 ng/g, representing a factor of 12.

Trace metals also behave in this manner, by increasing concentrations as particle size decreases. This has been reported by CARB (1984) as being analogous to the PCDF and PCDD behavior on incinerator fly ash. Trace metal concentration distributions on fine particles have been documented for incinerator emissions (Law and Gordon 1979) and for coal ash (Natusch et al 1974). Depending upon the volatile metal involved, the concentrations on incinerator-emitted ash can be one to ten times the concentration on fly ash trapped in the precipitator hoppers.

One researcher is known to have performed a study of PCDF and PCDD concentrations on incinerator ash as a function of particle size. Karasek et al. (1982) obtained sieved fractions of fly ash from electrostatic precipitators (not stack fly ash) at two incinerators. Analyses were performed for PCDDs on each fraction. These particles are larger than the airborne fractions emitted from the stack. Results from a French incinerator showed a clear trend of increasing concentration with decreasing particle size. Concentrations increased by three times for every particle size reduction of one-half. The incinerator on which these tests were performed is reported to be the Paris-Ivry facility, which is a Martin plant (Miller 1984). The other incinerator ash analyzed by Karasek did not show a clear trend between PCDD concentrations and particle size.

Other researchers (Tiernan et al. 1982) report that TCDD concentrations in the emissions of 3 um and 10 um particulate fractions from the Hempstead, L.I. plant were two and one-half times higher than TCDD concentrations in the 1 um and smaller fractions. However, this was a refuse derived-fuel (RDF) boiler plant, and not a mass-burn incineration plant. In addition, the process included the application of a chlorinated biocide to the waste to retard putrefaction. These factors alone indicate that particle structure and PCDF/PCDD emissions may be significantly different from that associated with a mass-burn plant. Furthermore, the plant was found to be emitting much more TCDD than was considered safe for nearby residents and was shut down pending reconstruction as a mass-burn plant. Barnes (1983) postulates that the carbon composition and the specific morphology of the particle in question has a significant effect on the adhesion qualities of PCDDs and PCDFs on particles. The differences in the process between the RDF and the mass-burn plants, as well as the extremely high emission rates of TCDD and other organic components, indicating poor combustion controls, suggests that the Hempstead, L.I. data may not be suitable for comparison to the BNYRRF.

For every increase in particle diameter by a factor of two, there is a commensurate increase in the particle surface area by a factor of four and an increase in weight by a factor of eight. If PCDF and PCDD are related to available particle surface area, as suggested by CARB (1984) and Kemp (1983), then a second particle twice as large as the first would have four times as much PCDF and PCDD, but it would also have eight times as much weight. Since the concentration is on a weight basis, the second particle would have four-eighths or one-half the concentration of the first.

Due to the similarity of the Paris-Ivry facility to the BNYRRF, the trend of increasing concentration with decreasing particle size is believed to be representative of conditions at the BNYRRF. This is further supported by the CARB study and the numerous studies that show higher concentrations in stack fly ash than in precipitator fly ash on currently operating mass-burn plants (Lustenhouwer et al. 1980; Taylor et al. 1983; Kemp 1983).

In order to predict the effect of the fabric filter on PCDF and PCDD emissions, the best approach available at this time is to calculate concentrations as a function of surface area. This shows a concentration increase factor of two for every size reduction of one-half (given the same weight of particles in each size category). Since this fits the general trend reported by researchers in this field, this approach has been taken in this assessment. Furthermore, it is assumed that all PCDDs and PCDFs are adsorbed on particulates and that there are no gaseous emissions. However, in actuality, it is likely that some portion of PCDFs and PCDDs will be in gaseous form.

In order to calculate the amount of adsorbed PCDF and PCDD materials that would be collected in a fabric filter, over and above that which would be collected in an electrostatic precipitator, relationships between particle size and PCDF/PCDD concentrations were developed. The following assumptions were made: (1) that all PCDF and PCDD compounds (observed by the Redford Study) are adsorbed on fly ash, and (2) that PCDF and PCDD materials on fly ash are distributed in proportion to the percent of total particle surface area available in each particle size category, and (3) additional fly ash collected by the fabric filter (over and above that which would have been collected by an electrostatic precipitator) has the same PCDF and PCDD concentration as calculated in (2) above.

Table 3-3 shows a particle size distribution of stack-emitted particulates from the Braintree Municipal Incinerator, which is a mass-burn resource recovery facility with an electrostatic precipitator. Also shown in Table 3-3 is the proportion of total particle surface area available for

TABLE 3-3

PARTICLE SIZE DISTRIBUTION
RESOURCE RECOVERY STACK EMISSIONS
(Electrostatic Precipitator Outlet)

Geometric Mean Particle Diameter (um)	Percent of Total Weight (%)	Percent of Total Surface Area (%)
15.0	12.8	1.5
12.5	10.5	1.5
8.1	10.4	2.2
5.5	7.3	2.3
3.6	10.3	5.0
2.0	10.5	9.2
1.1	8.2	12.9
0.7	7.6	16.6
LT 0.7	22.4	48.8

LT - Less than

Average of six test runs at resource recovery plant electrostatic precipitator outlet.

Actual test data from Braintree Municipal Incinerator, Braintree, MA. This is a mass-burn incinerator producing steam for industrial use. The incinerator has an electrostatic precipitator for fly ash control.

Ref: Golembewski et al. 1980

each particle size category, assuming spherical particles. This electrostatic precipitator has a lower particulate collection efficiency (75-90 percent) than an electrostatic precipitator that would be designed today (99+ percent). However, the basic performance characteristics still apply, i.e., high collection efficiency in the large particle size ranges and low collection efficiency in the small particle sizes. Since only the fraction representing the individual particle sizes emitted from the electrostatic precipitator is used in this analysis, and not the overall emission rate, the difference in efficiency between the Braintree facility and a more efficient unit would not significantly affect the analysis presented here. The particle size distribution would be shifted to a smaller size in a modern unit, meaning that the PCDDs and PCDFs would be concentrated in even smaller particles than those presented. Since the fabric filter is very efficient in the smaller particle size categories, the PCDD and PCDF emissions would then be even lower than presented. The particle size distribution data from Table 3-3 is combined with the Chicago Northwest and the Zurich-Josefstrasse PCDF and PCDD test data (Table 3-2) to predict how the PCDFs and PCDDs are concentrated within the individual size categories.

Under assumption (2) described above the controlling factor in the PCDF and PCDD concentration on fly ash particles is the available surface area. For example, 12.8 percent of the emitted fly ash weight and 1.5 percent of the particle surface area is comprised of the 15 um particles. From assumptions (1) and (2) above, 1.5 percent of the PCDD emitted from the stack is adsorbed on these particles. Similarly, 22.4 percent of the weight and 48.8 percent of the surface area of fly ash is comprised of particles less than 0.7 um. Assuming a 7.94 g/sec fly ash emission rate from the BNYRRF if an electrostatic precipitator were used (from PDEIS submitted previously), then for 15 um particles the PCDD concentrations are calculated as follows: the emitted PCDD, 0.015 times 9,540 ng/sec (Table 3-2), is divided by the weight of total fly ash in that size category, 7.94 g/sec times 0.128, to yield a concentration of 141 ng PCDD per g of fly ash. Similarly, for particles less than 0.7 um, 0.488 times 9,540 ng/sec, divided by 7.94 g/sec times 0.224, yields 2,618 ng PCDD per g fly ash. The results of these calculations are shown in Table 3-4.

For the case of a fabric filter instead of an electrostatic precipitator, the concentrations calculated above were used to compute emission

TABLE 3-4

CALCULATED CONCENTRATION OF PCDF AND PCDD IN FLY ASH EMISSIONS FUNCTION OF PARTICLE SIZE (ng/g)

Mean Particle Diameter (um)	PCDD Concentration (ng/g)	PCDF Concentration (ng/g)
15.0	141	1,224
12.5	172	1,492
8.1	254	2,209
5.5	379	3,291
3.5	583	5,070
2.0	1,053	9,150
1.1	1,890	16,429
0.7	2,624	22,812
LT 0.7	2,618	22,751

LT - Less than

Concentrations calculated from emission data in Table 3-2 and particle data in Table 3-3 rates of PCDD and PCDF from the BNYRRF. Particle size distribution by weight and a total fly ash emission rate was provided by the selected contractor (Signal-Resco). The total fly ash emission rate is 3.97 g/sec, while particle size distribution is shown in Table 3-5, first two columns. For 15 um particles the fly ash emission rate is 24 percent of 3.97 g/sec or 0.953 g/sec; the PCDD concentration on 15 um particles is 141 ng/g as calculated above and shown in Table 3-4. The PCDD emission rate for 15 um particle, therefore, is 141 ng/g times 0.953 g/sec., or 134 ng/sec. Similarly, for particles less than 0.7 um, 15 percent of 3.97 g/sec, or 0.596 g/sec, times 2,618 ng/g yields a PCDD emission rate of 1,560 ng/sec. The PCDD and PCDF emission rates are presented in the last two columns of Table 3-5; the total emission rates are 4,463 ng/sec PCDD and 38,791 ng/sec PCDF. These rates are slightly less than half the rates calculated for a similar resource recovery system with electrostatic precipitators (Table 3-2). Assuming the ratios between groups of isomers with the same number of chlorine substitutes, shown in Table 3-2, remains unchanged following collection by the fabric filter, the emissions of isomer groups from the fabric filter outlet would be as presented in Table 3-6.

3.7 Assessment of Predicted Emissions

From the data presented in Section 3.2.2 and Section 3.3, it is clear that PCDFs and PCDDs can be destroyed in a municipal combustion system. It is also clear that the most important consideration is not the source of the PCDFs and PCDDs but rather the creation of combustion conditions favorable for maximum destruction. These conditions apparently occur at the incinerators in Chicago and Zurich, both of which were tested and found to emit low levels of PCDF and PCDD. These systems include the same basic design as the proposed BNYRRF. In addition, the BNYRRF has further design improvements for the purpose of achieving lower emissions.

Combustion temperature of 650°C reported for the Chicago Northwest data is significantly lower than the design temperature of 980°C for the BNYRRF. The relationship between combustion temperature and PCDD emissions (Benfenati et al. 1983), determined through long-term testing on an incinerator in Italy, suggests that an 80 percent reduction in PCDD emissions on that

TABLE 3-5

PREDICTED PCDF/PCDD EMISSION RATES FROM BNYRRF FUNCTION OF PARTICLE SIZE (Outlet of Fabric Filter)

Mean Particle Diameter (um)	Weight[(a)] Percent %	Fly Ash Emission (g/sec)	PCDD Emission (ng/sec)	PCDF Emission (ng/sec)
15.0	24	0.953	134	1,166
12.5	11	0.437	75	652
8.1	7	0.278	71	614
5.5	5	0.199	75	655
3.5	7	0.278	162	1,409
2.0	7	0.278	293	2,544
1.1	14	0.556	1,051	9,135
0.7	10	0.397	1,042	9,056
LT 0.7	15	0.596	1,560	13,560
TOTAL	100	3.972	4,463	38,791

LT - Less than

(a) Weight percent fractions for particle sizes were calculated from data contained in personal communication from Mr. Andrew Szurgot, Signal-Resco to Ms. Susan Raila, Department of Sanitation, May 23, 1984.

TABLE 3-6

PREDICTED PCDF AND PCDD EMISSIONS FROM BNYRRF (Assuming that all PCDFs and PCDDs emitted are on particulate)

	Fraction	Concentration on Fly Ash (ng/g)	Mass Emission Rate (ug/sec)
Tri-CDF	.6173	6,029	23.946
Tetra-CDF	.1851	1,808	7.180
Penta-CDF	.0534	521	2.071
Hexa-CDF	.1275	1,245	4.946
Hepta-CDF	.0155	151	0.601
Octa-CDF	.0012	12	0.047
Total CDF	1.0000	9,766	38.791
Tri-CDD	.2321	261	1.036
Tetra-CDD	.1135	127	0.507
Penta-CDD	.1867	210	0.833
Hexa-CDD	.2862	322	1.277
Hepta-CDD	.1361	153	0.607
Octa-CDD	.0454	51	0.203
Total CDD	1.0000	1,124	4.463
2,3,7,8 Tetra-CDD	0.0073	8	.0326

This data assumes that all PCDF and PCDD emissions observed by Redford et al. 1981 were adsorbed on fly ash. The use of more efficient fabric filter would reduce PCDF and PCDD emissions from those levels.

incinerator would be achieved by raising the minimum combustion temperature from 650°C to 980°C. If this trend could be applied to both the Chicago, Northwest facility and the BNYRRF, then the emission data developed for the BNYRRF, which was based on the Chicago Northwest data, may be conservative. However, the location and accuracy of the temperature sensor at Chicago may be responsible for the difference. Whether the 650° C measurement at Chicago and the 980° C projection for BNYRRF are comparable or not, the use of auxiliary burners to ensure a minimum combustion temperature of 980°C at the secondary combustion zone at all times is a step aimed at assuring that emissions from BNYRRF will be at least as low as those from the Chicago Northwest facility.

Another positive step to minimize PCDF and PCDD emissions is the use of a fabric filter to collect ultra-fine fly ash particles. Since it is evident that these materials are more heavily concentrated in the sub-micron, or respirable size range, the use of a collector that is much more efficient in capturing particles in this range will further minimize PCDF and PCDD emissions.

In order to show the effects of the fabric filter, emissions are presented in two ways: (1) assuming all PCDFs and PCDDs observed from the test facilities passes through the collector in gaseous form and is emitted to the atmosphere, and (2) assuming that all PCDF and PCDD are adsorbed on fly ash particles, and therefore the emissions are reduced by the amount of fly ash and PCDD/PCDF collected in the fabric filter unit. As described above, it is apparent from test data that a portion of PCDF and PCDD emissions from incinerators are adsorbed onto fly ash. These two emission predictions will provide a range of estimates between a scenario where no more emissions are collected in the fabric filter in excess of the amount that would be collected in an electrostatic precipitator and a scenario where the fabric filter effectively reduces PCDF and PCDD emissions.

Another method of assessing the predicted emissions from the BNYRRF is a comparison of the concentrations of PCDF and PCDD on fly ash particles. Most of the data available from other incinerator systems consists of concentrations on particles collected in electrostatic precipitators. As described above, the concentrations on particles emitted from the stack are typically five to ten times those found on particles collected in electrostatic precipitators.

A compilation of PCDF and PCDD concentrations in fly ash is shown in Table 3-7, along with predicted concentrations from the BNYRRF. When the concentrations from the electrostatic precipitators are multiplied by five to ten times, the resulting estimated PCDF stack concentrations from the low and medium categories representing the 25 plants (Lustenhouwer, Olie, and Hutzinger 1980) compare favorably with the BNYRRF emission concentrations. This same comparison for PCDD, however, results in estimated stack concentrations that are five to ten times higher than the predicted BNYRRF concentrations. However, the PCDD data from the Buser study and the Karasek study (a Martin plant) compare favorably with the BNYRRF. Therefore, the predicted emissions from the BNYRRF appear to be in the same range as other comparable incinerators.

3.8 Summary

In summary, PCDF and PCDD emissions in incinerator effluents can originate from a number of sources and/or chemical reactions, such as being a part of raw refuse, being formed from precursors, and being formed from degradation products of materials commonly found in solid waste.

Whatever the cause of formation or occurrence, the combustion conditions necessary for destruction include a minimum of one to two seconds of gas residence time at a minimum combustion temperature of 900-1,000°C, very turbulent conditions in the high-temperature zone, and an air/fuel mixture with a slight excess of oxygen.

The incinerator design selected for the BNYRRF appears to fulfill the requirements for efficient combustion and maximum destruction of PCDFs and PCDDs. Furthermore, the use of auxiliary burners will assure that the minimum combustion temperature is consistently maintained. In addition, a more efficient fly ash pollution control device than is generally used on incinerators has been selected. Since at least some of the PCDF and PCDD

TABLE 3-7

CONCENTRATION OF PCDF AND PCDD IN FLY ASH FROM DATA IN AVAILABLE LITERATURE (ng/g)

	Boiler Passage(a)	Electrostatic Precipitator Fly Ash(a)	Electrostatic Precipitator Fly Ash(b) Low	Med.	High	Stack Flue Gas Fly Ash(b)	Electrostatic Precipitator Fly Ash(c)	Electrostatic Precipitator Fly Ash(d)	Predicted Stack Flue Gas BNYRRF
Tri-CDF	--	--	--	--	--	--	--	--	6029
Tetra-CDF	ND	1	13	111	223	460	170	--	1808
Penta-CDF	ND	4	42	196	510	960	--	--	521
Hexa-CDF	ND	30	109	361	870	1600	315	--	1245
Hepta-CDF	ND	40	89	177	407	1130	--	--	151
Octa-CDF	ND	10	20	18	26	140	48	--	12
Tri-CDD	--	--	--	--	--	--	--	--	261
Tetra-CDD	ND	2	5	54	110	100	126	ND	127
Penta-CDD	ND	8	31	182	488	800	--	8	210
Hexa-CDD	ND	30	80	326	1200	1370	443	28	322
Hepta-CDD	ND	60	190	288	902	1370	--	75	153
Octa-CDD	6	120	266	106	110	310	389	180	51

ND - Not detected (no detection limit reported)
Note: All data presented includes only solid particulate analysis; gaseous portion not included.

Ref. (a) Buser and Bosshardt 1978; simultaneous tests on boiler passage and stack
(b) Lustenhouwer et al. 1980; representing 80 analyses at 25 plants
(c) Olie et al. 1982; average of nine Dutch incinerators
(d) Karasek et al. 1982; average of three samples from a French Martin plan

materials will be adsorbed on particulate, less of these materials will be emitted and the exposure to the public will be less than if the less efficient electrostatic precipitator had been selected. However, the exact portion of PCDFs and PCDDs in the environment which can be attributed to any single source or process is impossible to determine.

Emission test data from a number of incinerators has demonstrated a wide range of PCDF and PCDD emissions spanning several orders of magnitude. High levels of emissions have been observed from several types of incinerators, indicating that operational factors have as much or more effect on PCDF and PCDD emissions than incinerator design. However, the lowest emissions were observed from incinerators with the same basic design as the BNYRRF. This is an encouraging point and may mean that effective operation and maintenance is easier on these units. The BNYRRF has also been designed with additional control features not found on the incinerators tested with even the lowest emissions.

The predicted PCDF and PCDD emissions from the BNYRRF are presented in Table 3-8. These emissions are presented in two ways as described in Section 3.6: (1) as if all PCDF and PCDD materials observed in previous tests were gaseous in nature and pass through the fabric filter without collection, and (2) as if all PCDF and PCDD materials observed in previous tests were adsorbed onto fly ash, part of which was subsequently assumed to be trapped in the fabric filter. The second case above is believed to be the most likely alternative. Given the uncertainty about the partitioning between gaseous and particulate PCDDs and PCDFs, it is not advisable to choose an amount of gaseous and particulate emissions, even though some data on this is presented in the literature. Obviously, the actual emissions from the BNYRRF could fall between these values if there is indeed a portion that is gaseous and a portion that is particulate in nature. Both cases are used in the following chapters to develop an exposure assessment and risk assessment.

TABLE 3-8

SUMMARY OF PREDICTED PCDF AND PCDD EMISSIONS
BROOKLYN NAVY YARD RESOURCE RECOVERY FACILITY
(Outlet of Fabric Filter)

	Case 1 All Gaseous Emissions (ug/sec)	Case 2 All Particulate Emissions (ug/sec)
Tri-CDF	51.18	23.95
Tetra-CDF	15.35	7.18
Penta-CDF	4.43	2.07
Hexa-CDF	10.58	4.94
Hepta-CDF	1.28	0.60
Octa-CDF	0.10	0.05
Total-CDF	82.92	38.79
Tri-CDD	2.22	1.03
Tetra-CDD	1.07	0.51
Penta-CDF	1.79	0.83
Hexa-CDD	2.73	1.28
Hepta-CDD	1.30	0.61
Octa-CDD	0.43	0.20
Total-CDD	9.54	4.46
2,3,7,8 Tetra-CDD		

Case 1 - assumes all PCDF and PCDD materials are gaseous, therefore no additional collection occurs in fabric filter above that collected by an electrostatic precipitator.

Case 2 - assumes all PCDF and PCDD materials are adsorbed on particulates, therefore additional fly ash collection in fabric filter reduces PCDF and PCDD emission.

The emission rates may vary between these values if there are gaseous and particulate fractions of PCDF and PCDD emissions.

4. Exposure Assessment for Emissions from the Proposed Brooklyn Navy Yard Resource Recovery Facility

4.1 Introduction

4.1.1 Purpose. In order to assess the impact of the emissions from the proposed BNYRRF on the general population, computer modeling was performed on the emission data in Chapter 3 to predict downwind concentrations of PCDFs and PCDDs in the ambient air, soil, dust and dirt. The predictions of ambient air concentrations of PCDFs and PCDDs quantifies potential population exposure through the inhalation pathway, while the deposition analysis provides a quantification of potential human exposure through the ingestion of contaminated dirt and dust, as well as through the dermal contact with these materials. This chapter provides discussions of these analyses and presents the results for use in the risk assessment in Chapter 5.

4.1.2 Approach. As discussed in Chapter 3, it is not known what fraction of the PCDF and PCDD emissions will be in gaseous form and what fraction will be adsorbed on fly ash. For that reason, the emissions from the BNYRRF were predicted in Chapter 3 according to two scenarios which define the limits of each of these possibilities: in the first scenario, emissions were calculated as if all PCDFs and PCDDs were gaseous and, in the second, as if all were adsorbed on particulates. The exposure assessment follows this same approach, designed to define the two scenarios of exposure possibilities. Exposures are calculated as if all PCDFs and PCDDs in the emissions are gaseous and as if all are adsorbed on particulates in proportion to available particle surface area.

Obviously, if all PCDFs and PCDDs are gaseous the only exposure pathway will be inhalation, while if they are all adsorbed on particulates, the pathways will include inhalation (of small respirable particles) and ingestion and dermal absorption (of deposited fly ash). If, in fact, the PCDFs and PCDDs in the emissions are partially gaseous and partially adsorbed on particulates, then the exposures will fall between the two cases presented here. Chapter 5 presents the risks projected for each of these cases.

4.2 Dispersion Model

The ambient air quality concentrations resulting from the BNYRRF were calculated using an air dispersion model that was deemed suitable by the regulatory agencies responsible for reviewing the environmental impacts of this project. The model calculated concentrations at several hundred ground-level and elevated locations. These locations are termed receptors, and the purpose in analyzing several hundred of them is to ensure that the concentrations at the areas of highest impact are calculated. Five years of meteorological data, measured at two nearby observation stations and reduced to magnetic tape, were used in the computer program to calcuate impacts from the specific air pollutant source. Emissions were predicted for both conditions described above (in which all PCDFs and PCDDs are in gaseous form and in which all are adsorbed on particulate) were calculated and the highest impacts of each case are presented separately.

In conjunction with preparation of the Preliminary Draft Environmental Impact Statement (PDEIS) for the Brooklyn Navy Yard, the consultant to the New York City Department of Sanitation (NYCDOS) prepared an air quality dispersion analysis designed to assess impacts at ground-level and at elevated (building rooftop) receptors. The model selected by the consultant and the New York City Department of Environmental Protection (NYCDEP), as the most appropriate for analyzing all air quality impacts resulting from the BNYRRF stack emissions, was the Multiple Point Source Gaussian Dispersion Algorithm with Optional Terrain Adjustment (MPTER).

MPTER is a computer dispersion program developed by the USEPA Meteorological Laboratory for analyzing air quality impacts from a number of emission sources at both ground-level and elevated receptors. The terrain adjustment feature allows the program to estimate the amount of plume reflection (and subsequent concentration increase) at elevated terrain points. Elevated receptors, such as building rooftops, balconies, windows, etc., are analyzed as if they are points in space, unaffected by aerodynamic impacts from the buildings themselves.

The MPTER model has been further modified specifically for use in the urban environment. The steady-state Gaussian dispersion algorithm, which is the basis for the MPTER program, was originally used only with the Pasquill-Gifford (P-G) dispersion coefficients. Dispersion coefficients are the factors that determine the dilution rates along each trajectory evaluated in the model. Therefore, these coefficients are a key aspect to any dispersion modeling analysis. The P-G coefficients were empirically developed by ambient testing in rural terrain. These coefficients provide the amount of pollutant dispersion as a function of atmospheric conditions and downwind distance, as if the source and receptor were located in a rural area.

The modification of MPTER to MPTERU, which was undertaken by the NYCDEP, Bureau of Science and Technology, allows the user of the program the option of P-G dispersion coefficients or McElroy-Pooler (M-P) coefficients. The M-P coefficients were also empirically determined by ambient testing, but the testing was performed in an urban area (St. Louis, Missouri). The M-P coefficients are therefore considered by the NYCDEP to be more appropriate for dispersion analyses of point sources in New York City. This model is considered to be a conservative model and is used for most source-receptor analyses performed for review by the NYCDEP's, Office of Environmental Impact.

The MPTERU program with the M-P coefficients was used to determine the concentrations at all potential receptors in the area of significant impact, including ground-level receptors within 25 km of the Brooklyn Navy Yard, as well as elevated receptors in Brooklyn, Queens and Manhattan.

Meteorological data collected at LaGuardia Airport and Fort Totten was selected as the most representative data for the study area. The wind, temperature, mixing height, and sky condition data collected during the period 1975-1979 is the most recent available data in the format suitable for MPTERU, and was used to compute hour-by-hour impact concentrations at each receptor. The hourly concentrations at each receptor were then averaged for each year to arrive at the annual average concentration.

Normalized concentrations were developed by the model in order to address the various pollutants that may be emitted by the Brooklyn Navy Yard facility. Normalized concentrations (using a gram per second emission rate), were calculated for each potential receptor and each hour of meteorological data used by the program. After compiling the results, the maximum annual average ground-level and maximum annual average elevated-receptor normalized concentrations were determined. The concentration of a particular pollutant could then be determined by multiplying the normalized concentration times the emission rate of that pollutant (g/sec) to obtain the ambient concentration ug/m^3. The maximum ground-level annual average normalized concentration was 0.0238×10^{-6} g/m^3, and occurred approximately 900 meters southeast of the stack; the maximum elevated-receptor normalized concentration was $.0240 \times 10^{-6}$ g/m^3, and occurred at the same location three stories above the maximum ground-level impact. For all the purposes of the following analyses, both ground-level and elevated receptor impacts are considered to be 0.024×10^{-6} g/m^3 for a one g/sec emission rate.

When using this dispersion analysis impact methodology and the PCDF and PCDD emission calculations from Case 1 of Table 3-8, it is assumed that all PCDFs and PCDDs are emitted, and that they behave in the atmosphere, as a gas. Application of these emission rates to the maximum normalized concentrations results in the impact concentrations shown in Table 4-1. Since these concentrations are extremely small, the units presented are picograms per cubic meter (pg/m^3 or 10^{-12} g/m^3).

The second case is that in which all the PCDF and PCDD emissions are adsorbed onto fly ash particles. In this case, the emissions would be as presented in Table 3-8, Case 2, where PCDFs and PCDDs are assumed to be emitted as particulate matter. Several important differences between this case and the one described above would prevail, including:

- some portion of the total mass of PCDF and PCDD emissions as presented in Case 1, would be trapped by the fabric filter;
- some of the heavier particles would settle to and remain on the ground and would not be available for inhalation;

TABLE 4-1

PREDICTED MAXIMUM ANNUAL AVERAGE CONCENTRATIONS OF PCDFs AND PCDDs AT GROUND-LEVEL AND ELEVATED RECEPTORS DUE TO EMISSIONS FROM THE BROOKLYN NAVY YARD FACILITY

Case 1: All PCDF and PCDD Emissions Are Gaseous

	Maximum Concentration at Ground-Level and Elevated Receptors (pg/m^3)
Tri-CDF	1.2283
Tetra-CDF	0.3684
Penta-CDF	0.1063
Hexa-CDF	0.2539
Hepta-CDF	0.0307
Octa-CF	0.0024
Total-CDF	1.9900
Tri-CDD	0.0533
Tetra-CDD	0.0257
Penta-CDD	0.0430
Hexa-CDD	0.0655
Hepta-CDD	0.0312
Octa-CDD	0.0103
Total-CDD	0.2290
2,3,7,8, Tetra-CDD	0.00168

pg/m^3 - picograms per cubic meter (10^{-12} g/m^3)

NOTE: These concentrations were calculated from mass emission rates in Table 3-8 and normalized concentrations presented in the PDEIS. These concentrations assume no chemical/biological degradation or transformation of PCDF and PCDD compounds.

- some particles that are reflected from the ground (remaining suspended in the ambient air) may not be inhalable and/or respirable because the size would exceed that which is generally accepted as possible for pulmonary deposition.

The amount of particles and PCDF/PCDD that would be deposited on the ground in this case is discussed in Section 4.3.

In order to present a conservative analysis of the inhalation exposure in this case, the particulates that deposit on the ground are also assumed to be available for inhalation. However, since the larger particle deposit and the smaller particles have the higher concentrations, this is only one to two percent of the total PCDDs and PCDFs emitted. Therefore, there is a slight double-count in the inhalation exposure. A mass balance of the process would show the amount deposited on the ground should be subtracted from the amount available for inhalation. However, since this is a small amount, it was not subtracted, adding to the conservatism of the model.

The ambient air PCDF and PCDD concentrations for Case 2, where all PCDFs and PCDDs are adsorbed onto particulates, are shown in Table 4-2. As described above, for any single receptor the ambient concentrations are directly proportional to the emission rates. Since the emission rates for Case 2 are slightly less than half the emission rates under Case 1, so are the ambient concentrations. If the total PCDF and PCDD emissions contain fractions of gaseous and particulate materials, the actual concentrations will be between the values presented in Table 4-1 and those presented in Table 4-2.

4.3 Deposition Model

The pathway of ingestion and dermal exposure for particles emitted from the Brooklyn Navy Yard facility stack would originate with solid particulates that settle to the ground and are mixed with ambient dust, dirt and soil. In order to determine the rate at which the particles settle to the ground surface, a computer model with specific capability to analyze particulate deposition rates was selected. This model is the Industrial Source

TABLE 4-2

PREDICTED MAXIMUM ANNUAL AVERAGE CONCENTRATIONS OF PCDFs AND PCDDs AT GROUND-LEVEL AND ELEVATED RECEPTORS DUE TO EMISSIONS FROM THE BROOKLYN NAVY YARD FACILITY

Case 2: All PCDF and PCDD Emissions Are Adsorbed on Particulate

	Maximum Concentration at Ground-Level and Elevated Receptors (pg/m^3)
Tri-CDF	0.5747
Tetra-CDF	0.1723
Penta-CDF	0.0497
Hexa-CDF	0.1187
Hepta-CDF	0.0144
Octa-CF	0.0011
Total-CDF	0.9309
Tri-CDD	0.0249
Tetra-CDD	0.0012
Penta-CDD	0.0120
Hexa-CDD	0.0306
Hepta-CDD	0.0146
Octa-CDD	0.0049
Total-CDD	0.0882
2,3,7,8, Tetra-CDD	0.000782

pg/m^3 - picograms per cubic meter (10^{-12} g/m^3)

NOTE: These concentrations were calculated from mass emission rates in Table 3-8 and normalized concentrations presented in the PDEIS. These concentrations assume no chemical/biological degradation or transformation of PCDF and PCDD compounds.

Complex (ISC) model developed under the sponsorship of USEPA by a private contractor (H.E. Cramer Co. 1979). A deposition prediction methodology is an optional feature of that model. The deposition algorithm was developed under contract to the U.S. Army (Dumbauld et al. 1976). The model is not equipped to handle terrain features or elevated receptors when calculating deposition rates, and the model is not able to account for any physical transformation or change in particle size occurring in the atmosphere. Therefore, some inaccuracies may be introduced due to flow obstruction by buildings, and by particle size changes. However, the USEPA technical branch of the Office of Air Quality Planning and Standards recommends that this model be used whenever the assessments of impacts caused by dry deposition from a stationary point source are necessary. Although this model is not as easily validated as the more commonly used dispersion model, it is the only one available that can quantify deposition rates near a point source.

The long-term (ISCLT) model version was used to calculate annual deposition rates at ground-level receptors. The annual deposition rates were computed at 612 receptor points extending out to 12 km from the proposed site. The deposition rates were calculated using meteorological conditions observed over a five-year period from 1966 to 1970 at the LaGuardia Airport weather station. The emission rates from Case 2 in Table 3-8, where all PCDFs and PCDDs were assumed to be adsorbed on fly ash, were used in this analysis. If only a portion of the PCDFs and PCDDs are adsorbed on fly ash, then the deposition rates will be less than those presented.

Figure 4-1 shows the distribution of annual deposition rates around the Brooklyn Navy Yard. The units of these lines of constant deposition are milligrams of particulate fly ash deposited per square meter per year. The point of maximum deposition is located approximately 3 km southwest of the Brooklyn Navy Yard near the waterfront and Atlantic Avenue. Other points of high deposition occur 3 km east-southeast and 3 km south-southeast of the facility. The maximum annual particulate fly ash deposition rate is 4.613 mg/m^2 per year. The deposition rate gradually decreases between 3 km distance from the BNYRRF to 9 km, where it is 1-2 mg/m^2 per year, and decreases

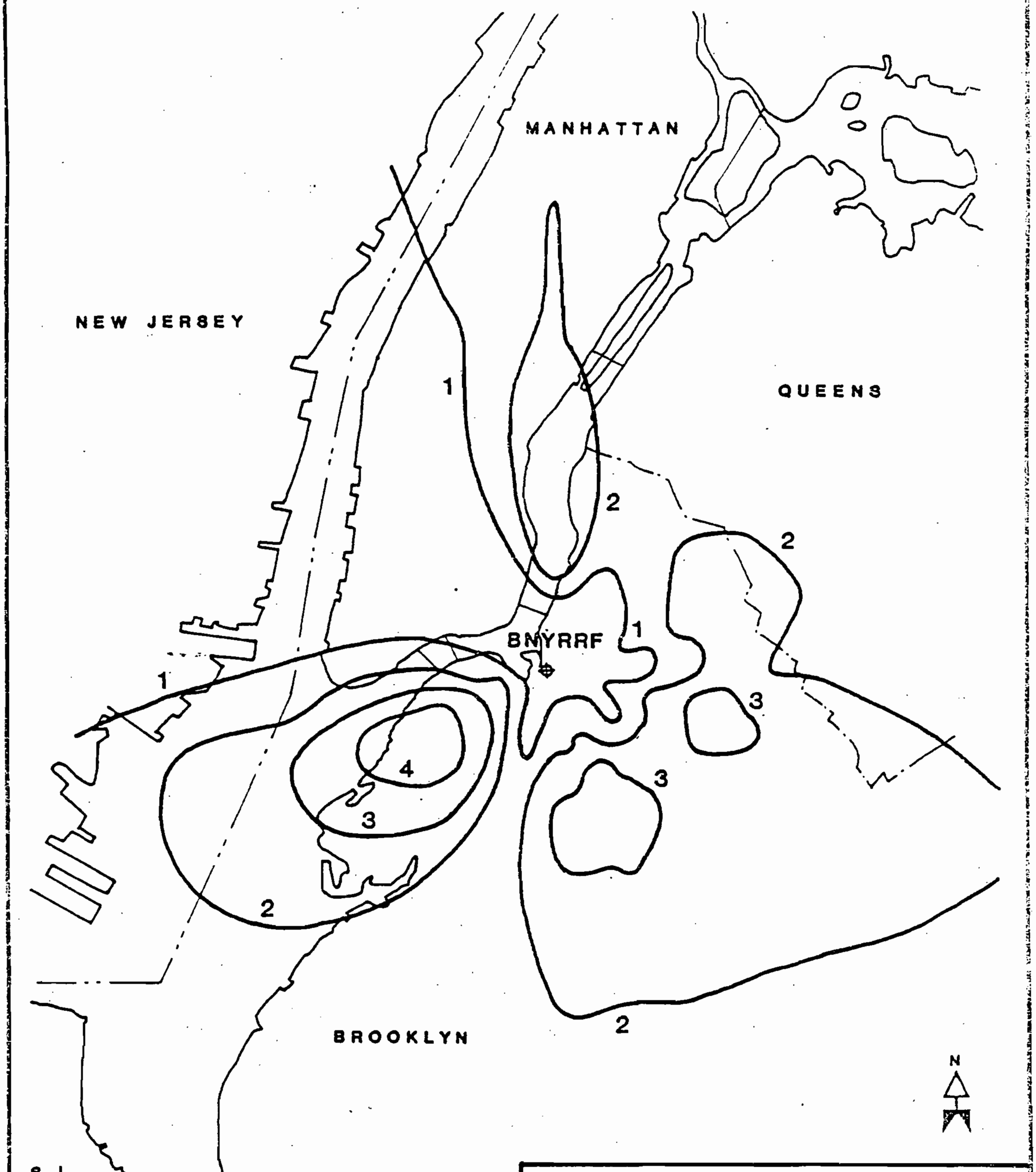

FIGURE 4-1

ANNUAL FLY ASH DEPOSITION RATES (mg/m^2-yr)

(AVERAGE FOR FIVE YEARS OF METEOROLOGICAL DATA)

FRED C. HART ASSOCIATES, INC.

even more gradually from that distance. This is due to the fact that very small particles are emitted from the fabric filter, and most of these small particles will either travel long distances before settling or will not settle at all. From the empirical relationship reported by Dumbauld et al (1976), the proportion of fly ash emitted from the BNYRRF that will ultimately settle to the ground is determined as shown in Table 4-3. This is computed from the reflection coefficients, i.e., the fraction of fly ash in a particular particle size category that is reflected from the ground when the carrier (air) is reflected from the ground surface. This is also the fraction of fly ash which remains suspended in air and does not settle at all. The reflection coefficient is a function of the particle settling velocity, which is a function of particle size and density.

The distribution of fly ash particles that deposit on the ground surface is a function of the emitted particle size distribution and the reflection coefficients for each particle size category. For example, from Table 4-3, 20 percent by weight (100 minus reflection coefficient) of the particles with a mean diameter of 15 um will deposit. Since, from Table 3-5, 24 weight percent of the fly ash emission from the BNYRRF are in the 15 um category, then 0.20 times 0.24 times 3.97 g/sec emitted fly ash, or 0.191 g/sec, will settle and will comprise the 15 um category of the deposited fly ash. This calculation was performed for each particle size category, yielding a total of 0.346 g/sec or 9 percent of the fly ash emitted.

The fraction of depositing particles in the 15 um size category is 0.191 g/sec divided by 0.346 g/sec, or 55 percent by weight of all particles that settle, while the concentration of PCDD is 141 ng/g (Table 3-4). For each particle size category, the fractions of total deposition weight times the PCDD concentrations were calculated, and these values were summed. The results were 194 ng/g PCDD and 1,682 ng/g PCDF; multiplying these concentrations by the total fly ash deposition rate of 0.004613 g/m^2 per year yields 0.895 ng/m^2 PCDD and 7.759 ng/m^2 PCDF per year. The breakdown of isomer groups of PCDF and PCDD are shown in Table 4-4 for the highest deposition rate.

TABLE 4-3

CHARACTERISTICS OF PARTICLE AERODYNAMICS

Mean Particle Diameter[a] (um)	Aerodynamic Settling Velocity (m/sec)	Reflection Coefficient[b] (Dimensionless)	Fraction of Particles Deposited **
15.0	0.007	0.80	0.20
12.5	0.005	0.82	0.18
8.1	0.002	0.85	0.15
5.5	0.001	0.90	0.10
3.6	0.0004	0.95	0.05
2.0	0.0001	1.0	0
1.1	0.00004	1.0	0
0.7	0.00002	1.0	0
LT 0.7*	0.000004	1.0	0

LT - Less than

* Estimated at 0.35.

** Fraction of particles deposited equals one minus the refraction coefficient.

Ref: (a) Golembiewski et al 1980
(b) Dumbauld et al 1976

TABLE 4-4

PREDICTED MAXIMUM ANNUAL PCDF/FCDD DEPOSITION RATES BROOKLYN NAVY YARD FACILITY

	Maximum Annual Deposition Rate (ng/m^2)
Tri-CDF	4.790
Tetra-CDF	1.436
Penta-CDF	0.414
Hexa-CDF	0.990
Hepta-CDF	0.120
Octa-CDF	0.009
Total-CDF	7.759
Tri-CDD	0.208
Tetra-CDD	0.101
Penta-CDD	0.167
Hexa-CDD	0.256
Hepta-CDD	0.122
Octa-CDD	0.041
Total-CDD	0.895
2,3,7,8, Tetra-CDD	0.0065

4.4 Predicted Maximum Concentrations of PCDFs and PCDDs in Soil, Dirt, and Dust

Where the fly ash particles land on ambient soil, a conservative interpretation would be that the fly ash particles mix within the top centimeter of ambient soil or dust by mechanical means without resuspension and reentrainment. A typical soil density is 1.6 g/cm^3, and the concentrations of PCDF and PCDD compounds mixed in a layer of soil one centimeter thick are presented in Table 4-5 for accumulations after one year. Subsequent accumulations can be determined by multiplying these values by the number of accumulating years. Of course, this would not account for any degradation or volatilization during this time period. Due to the extremely low PCDF and PCDD concentrations observed, the units presented are femtograms per gram of soil (fg/g or 10^{-15} g/g).

Particles depositing on hard smooth surfaces outdoors will settle at the rates presented in Table 4-4 along with total particulate from other sources. These particles would be subject to frequent washout due to deliberate washing and natural rains. Therefore, an accumulation rate would not be appropriate. Instead, the fly ash particles are assumed to be diluted with settleable ambient particulates at all times. Exposure concentrations will conservatively remain the same even though the particles may be further diluted by surface dirt and dust. The settleable particulate data has been provided by the City of New York Department of Environmental Protection as total dustfall data actually measured in Brooklyn. This was 0.62 mg/cm^2 per month, or 74.4 g/m^2 per year (Nudelman 1984). The concentrations of PCDFs and PCDDs in settleable dirt are presented in Table 4-6 based upon fly ash dilution with this settleable particulate dustfall rate from other sources. These concentrations are not likely to change over time because total particulate and fly ash will be depositing (and washing away) at steady rates. The units are in picograms per gram of dirt.

It is inevitable that some street dirt and soil will enter the homes in the area and it is possible that some of this soil and dirt will contain deposited particulate fly ash from the Brooklyn Navy Yard stack emissions. Because of the highly variable nature of the independent parameters, it is

TABLE 4-5

CONCENTRATIONS OF PCDF AND PCDD MATERIALS IN SOIL AREAS OF MAXIMUM DEPOSITION RATE

BROOKLYN NAVY YARD FACILITY

	Concentrations in Soil After One Year(fg/g)
Tri-CDF	299
Tetra-CDF	90
Penta-CDF	26
Hexa-CDF	62
Hepta-CDF	8
Octa-CDF	0.6
Total-CDF	486
Tri-CDD	13
Tetra-CDD	6
Penta-CDD	10
Hexa-CDD	16
Hepta-CDD	8
Octa-CDD	3
Total-CDD	56
2,3,7,8 Tetra-CDD	0.41

NOTE: The concentrations presented in this analysis assume no chemical/ biological degradation or transformation of PCDF and PCDD compounds.

fg/g - femtograms per gram (10^{-15} g/g)

TABLE 4-6

CONCENTRATIONS OF PCDF AND PCDD MATERIALS IN SETTLEABLE PARTICULATE ON OUTDOOR SURFACES AREAS OF MAXIMUM DEPOSITION RATE

BROOKLYN NAVY YARD FACILITY

	Concentrations in Dirt (pg/g)
Tri-CDF	64
Tetra-CDF	19
Penta-CDF	6
Hexa-CDF	13
Hepta-CDF	2
Octa-CDF	0.1
Total-CDF	104
Tri-CDD	3
Tetra-CDD	1
Penta-CDD	2
Hexa-CDD	3
Hepta-CDD	2
Octa-CDD	0.6
Total-CDD	12
2,3,7,8 Tetra-CDD	0.087

NOTE: The concentrations presented in this analysis assume no chemical/biological degradation or transformation of PCDF and PCDD compounds.

pg/g - picograms per gram (10^{-12} g/g) impossible to determine through physical modeling how much of this material will enter homes. A number of studies, however, that have been performed correlating ambient lead concentrations in outdoor dirt and soil with ambient lead concentrations in interior house dust, have been used to estimate the amount of particulates entering the home.

Assuming that the relationship between indoor/outdoor levels of PCDF and PCDD correspond to the relationships for environmental lead, the proportion of the amount of lead found indoors compared with the amount found outdoors can be used to estimate the amount of PCDF/PCDD materials deposited indoors. In a recent Dutch study (Brunekreef et al. 1983), where the home environments of 195 children were analyzed, the proportions of lead on the floors of suburban and inner city homes were 10-25 percent of the lead on city streets. Furthermore, deposition rates were measured in the Dutch study, which correspond to accumulation times of 13-30 days; i.e., after 13-30 days the floors would be cleaned of accumulated dust. Assuming the highest values of these ranges for conservatism, 25 percent of outdoor deposition and 30 days accumulation time, the amount of PCDF/PCDD materials found indoors in the area of maximum deposition from the Brooklyn Navy Yard would be as presented in Table 4-7. A number of researchers have concluded that the weight concentrations (g/g) of lead and other toxic metals in household dust were approximately equal to those in street dust. Therefore, the concentrations presented in Table 4-6 on a weight basis can be assumed to be equivalent to the PCDF/PCDD concentrations in household dust.

4.5 Summary

Impacts of PCDF and PCDD emissions from the BNYRRF are manifested in ambient air concentrations (inhalation exposure) and particle deposition on horizontal surfaces (ingestion and/or dermal exposure). Maximum inhalation exposure would occur if the PCDFs and PCDDs observed through actual testing of other incinerators were entirely gaseous in nature. This maximum impact, although extremely low, would occur at ground-level approximately one kilometer Southeast of the plant site, and at rooftop level 2.27 km Southwest of the site. Obviously, if these materials were gaseous in nature there would be no deposition, and therefore, there would be no ingestion and/or dermal

TABLE 4-7

PREDICTED AMOUNT OF PCDD AND PCDF ACCUMULATION ON INDOOR SURFACES AREA OF MAXIMUM DEPOSITION RATE

BROOKLYN NAVY YARD FACILITY

	Accumulation (pg/m^2)
Tri-CDF	100
Tetra-CDF	30
Penta-CDF	9
Hexa-CDF	21
Hepta-CDF	2.5
Octa-CDF	0.2
Total-CDF	163
Tri-CDD	4
Tetra-CDD	2
Penta-CDD	3.5
Hexa-CDD	5
Hepta-CDD	2.5
Octa-CDD	0.9
Total-CDD	18
2,3,7,8 Tetra-CDD	0.135

NOTE: Indoor deposition rate is equal to 25 percent of outdoor deposition rate and accumulation time equals 30 days.

exposure. Therefore, maximum inhalation exposure does not necessarily indicate maximum health risk since the exposures resulting from deposition would not occur. However, if the PCDFs and PCDDs are particulate in nature, total PCDF and PCDD emissions would be roughly halved, due to high efficiency fabric filter collection of fine particles on which PCDFs and PCDDs would be concentrated, with a concomitant reduction in ambient air concentrations. In this case, the deposition rates would be at the highest levels. Unfortunately, with the state-of-the-art sampling technology, it is impossible to assess the actual partition between gaseous and particulate PCDF and PCDD emissions. Only total emissions are quantifiable; therefore, both cases have been evaluated and represent a range of potential exposure.

If the PCDD materials are emitted as particulate matter, deposition of particles would occur with the points of maximum deposition occurring approximately three kilometers from the stack between the southwest and southeast quadrants. Three pathways have been evaluated for the exposure from deposition of PCDF and PCDD materials: (1) concentration in soil, (2) concentration in street dirt, and (3) concentration in house dust. All pathways have been evaluated using the maximum deposition rates and the conservative assumption that no isomer transformation, volatilization, chemical degradation, biological degradation, resuspension, or reentrainment occurs. Despite the conservatism applied in this assessment, the impacts are extremely low as shown in Table 4-8. These impact data are utilized in Chapter 5 to calculate risk levels based on accepted modeling techniques and available information.

TABLE 4-8

SUMMARY OF MAXIMUM IMPACTS FROM BROOKLYN NAVY YARD EMISSIONS

	Ambient Air Concentration (pg/m^3)[a]	Concentration in Soil (pg/g)[b]	Concentration in Street and Household Dirt (pg/g)[c]
Case 1: Gaseous PCDF and PCDD			
PCDF	1.9900	-	-
PCDD	0.2290	-	-
2,3,7,8 TCDD	0.00168	-	-
Case 2: Particulate PCDF and PCDD			
PCDF	0.9309	0.486	104
PCDD	0.0882	0.560	12
2,3,7,8 TCDD	0.000782	0.00041	0.087

(a) Annual average concentration at point of maximum impact.
(b) After accumulation of one year at point of maximum impact.
(c) Annual average deposition concentration at point of maximum impact.

CHAPTER 5.0

Risk Assessment

5.1 Background

5.1.1 Introduction.

The purpose of this chapter is to provide an evaluation of the potential hazards associated with the predicted dioxin emissions from the BNYRRF. The process by which this evaluation will be performed is known as a risk assessment. A risk assessment compares the concentrations of contaminants known or predicted to cause a toxic effect to the predicted level of exposure of local populations. The difference between the two levels constitutes the level of risk projected for the facility.

The risk assessment in this chapter will be performed in four steps. First, we will identify levels of estimated "risk" to human health associated with different concentrations of PCDDs and PCDFS. The definition of risk will be based upon the toxic effect dose/response data, standards, criteria, and guidelines of various state, federal, and international regulatory agencies.

Next, utilizing the data in Chapter 4 to predict the maximum concentration of PCDDs and PCDFs in the air, dirt, soil and indoor surfaces, we will determine predicted levels of exposure calculated as a "worst case" daily intake for residents located in the areas of highest potential impact.

The third step in the risk assessment will compare the maximum ground-level ambient air concentrations of PCDDs and PCDFs resulting from predicted emissions from the BNYRRF, with standards and guidelines promulgated by different regulatory agencies in this country and abroad. This comparison will constitute one criterion of risk.

Finally, risk levels will be estimated by comparing predicted worst-case daily PCDD and PCDF intake levels to levels or concentrations known or suspected to cause a toxic effect. This will act as a second criterion of risk.

5.1.2 Limitations of the Risk Assessment Process.

In reviewing the following risk assessment it is important to keep in mind the methodological limitations of the risk assessment process.

First, a risk assessment, while based upon scientific considerations, often requires the use of assumptions derived using sound technical and scientific judgement. The use of assumptions rather than scientific data are often necessary because frequently there is an inadequate data base on the environmental fate, transport, and bioavailibility of contaminants such as PCDDs and PCDFs. For example, the bioavailability of PCDD adsorbed to fly ash (i.e. the amount of PCDD that can be absorbed through the skin, digestive or pulmonary system) is not known. In the absence of direct experimental data, an estimate or range of estimates is applied, based on the best available data. For example, we might have to use existing information on the bioavailability of PCDDs adsorbed to soils to extrapolate to fly ash.

Second, a risk assessment frequently requires extrapolation of high-dose animal feeding studies to estimate risk to humans at the extremely low dosages or concentrations of contaminants found in the environment. Data are not available to determine the actual shape of a dose/response curve (i.e., the level of risk), or the best method to extrapolate risk at low dosages. Accordingly, there is a great range of uncertainty regarding actual risk (at very small concentrations) for a given contaminant (OSTP, 1984; EPA, 1984a; NRC, 1983).

Due to the necessity of using such estimates or assumptions, the degree to which predictions of risk conform to actual risk, (i.e. the quality of the assessment) can only be as good as the quality and degree of accuracy in the assumptions applied. Clearly, any assumptions used in risk assessment can have significant impacts on the overall findings and determination of levels of risk.

In the absence of sufficient data or knowledge about such issues as the degree of exposure, intake, fate and bioavailability of contaminants, the typical risk assessment uses the most reasonable assumptions possible, erring on the side of public health. Typically, "worst-case" scenarios or conservative assumptions are used in the assessment process rather than most probable case scenarios to provide an added safety factor. A conservative assumption is one which increases the likelihood that a substance represents a hazard to public health.

However, the use of a number of "worst-case" or conservative assumptions carries the danger that the estimate of risk can become vastly overstated and, therefore, unrealistic. Risk assessments that rely upon "worst-case" scenarios must be critically evaluated with regard to the degree of realism in the model used to estimate risk.

To summarize, the product of a risk assessment is typically a description of the worst possible scenario or upper bound to risk, coupled with an assessment of the accuracy of the assumptions used to estimate the risk. Actual risks are likely to be substantially lower. These results of a risk assessment are then used for risk management purposes, to judge whether the upper bound of risk levels are acceptable in comparison to any proposed benefits.

5.2 Determination of "Risk"

Historically, there have been two approaches to estimating risk levels for exposure to toxic agents. One approach involves calculating an "Acceptable Daily Intake" (ADI) by applying a safety factor to doses of the agent that did not produce an observed effect in laboratory animals (no observed effects level, NOEL). This approach is typically used for non-carcinogenic toxic effects. The second approach relies on the use of mathematical models to extrapolate experimental dose-response information obtained from animal exposure studies using high dosage levels, to the low levels likely to be encountered by human populations. This latter approach is used for carcinogens and generally assumes that there is no threshold for the response being extrapolated, i.e., that any dose, no matter how small, will pose some risk. It was originally used for radiation damage, but has found widespread use for estimating risks due to chemical carcinogens.

5.2.1 ADI/NOEL Approach. As discussed previously, 2, 3, 7, 8-TCDD has a variety of toxic effects on laboratory test animals, including embryotoxicity and teratogenicity. Effects have also been observed in various organs and systems including the thyroid, liver, and skin, as well as the immunologic system. The 2,3,7,8-TCDD isomer has also been demonstrated to be an animal carcinogen.

Normally, an ADI is not derived from a NOEL for compounds which have been found to be carcinogenic. However, 2,3,7,8-TCDD has not been proven to be an initiator of neoplastic growth (Kim, 1984; Kimbrough, 1983; NRCC, 1981). In light of this fact, several agencies have found it appropriate to use a NOEL to calculate a guideline or standard. For 2,3,7,8-TCDD, a no-observed-effect level of 1 nanogram per kilogram of body weight per day (1×10^{-9} g/kg-day) in rats has been reported in both a three generation reproduction study (Murray, et al., 1979) and a two year oncogenic study (Kociba et al., 1978). On the basis of these studies, regulatory agencies in Canada, the Netherlands, and elsewhere have developed guidelines or standards by applying safety factors ranging from 100 to 250 to the NOEL. For example, the Netherlands has developed an ADI for 2,3,7, 8-TCDD of 0.004 ng/kg/day.

Several authors have questioned whether 1 ng/kg/day represents a true NOEL (Kimbrough, 1983; EPA 1984). They cite Allen, et al. (1979), who observed effects on reproductive outcomes in female rhesus monkeys fed 1.8 ng TCDD/kg-day day over a six-month period. These effects indicate that a no-effect level has not been determined in this primate species. In addition, no long-term multigeneration studies have been conducted in this species. Accordingly, they recommend a more conservative approach to establishing an ADI by applying a 1,000-fold safety factor to the NOEL reported by Allen of 1.8 ng/kg-day. This would result in an ADI equal to 1.8 pg/kg-day. NOELs have not been determined for other PCDD and PCDF isomers.

A list of the standards and guidelines established by regulatory agencies or published by various authors using the ADI/NOEL approach is provided in Table 5.1. The assumptions made in converting an ADI to a standard are provided in Section 5.3.

5.2.2 Extrapolating Risks from High Dosage Carcinogenic Bioassays. For suspected carcinogens, the approach used to determine excess carcinogenic risk is to extrapolate dose/response (i.e. tumor count) data from high-dose animal studies to low-dose risk levels by application of various mathematical extrapolation models. [The true shape of the dose/response curve at low dosages is not known. From a mathematical point of view, determining the actual shape of the dose/response curve at low dosages through low-dose animal feeding studies, is probably impossible due to the enormously large and costly number of animals that would be required (NRC, 1983)]. A conversion factor is then applied to convert animal dosage to human dosage. The conversion factor is often based upon relative differences in weights or surface areas.

A number of mathematical models can be applied to the dose-response extrapolation. The linear non-threshold model has been adopted as the primary basis for risk extrapolation in the low-dose region of the dose/response relationship. Despite its somewhat limited scientific basis, it is considered the best of any of the current mathematical extrapolation models. The risk estimates resulting from this model should be regarded as conservative, representing the most probable upper limit for the risk; i.e., the true risk is not likely to be higher than the estimate, but it could be lower.

The use of the linear non-threshold model to extrapolate risk may be a particularly conservative assumption for TCDD since TCDD may act as a promoter rather than as an initiator in carcinogenesis (Kimbrough, 1983). The use of the linear extrapolation model is believed to produce an overestimate of risk for carcinogens that are primarily promoters. This argument, however, is open to challenge. (NRC, 1983)

TABLE 5-1

DIOXIN STANDARDS AND CRITERIA USING ADI/NOEL APPROACH

Agency	Description	Basis for Standard	Standard/Criteria/or ADI
Canada[1]	Ambient air quality guideline for mixture of PCDDS and PCDFs	NOEL of 1 ng/kg-day safety factor of 100	30 pg/m^3 PCDDs in ambient air or $\frac{[PCDD]}{30\ pg/m^3} + \frac{[PCDF]}{30\ pg/m^3 \times 50} = 1$
Netherlands[2]	Acceptable daily intake	NOEL of 1 ng/kg-day safety factor of 250	12 pg/m^3 PCDD in ambient air [Derived from ADI-assumes 60 kg person ventilating at 20m^3/day. PCDD 100% bioavailable]
Kimbrough[3] (CDC)	Used ADI as one method to determine health implication of dioxin contaminated soil	LOEL of 1.8 ng/kg-day safety factor of 1000.	ADI equals 1.8pg/kg-day
NYSDOH[4]	Developed ADI to determine re-entry criteria for Binghamton office building closed down due to a transformer fire.	NOEL of 1 ng/kg safety factor of 500	ADI equals 2 pg/kg-day 15 pg/^{3}-TCDD Equivalents; Standard for Worker exposure 40-hour work week

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1. Harding, D.H. 1982. Chlorinated dioxins and chlorinated dibenzofurans: ambient air guideline. Health Studies Service, Special Studies and Services Branch, Ministry of Labor.

TABLE 5-1 (Continued)

DIOXIN STANDARDS AND CRITERIA USING ADI/NOEL APPROACH

2. Heigden, et al. 1982. Report DOC/LCM 300/292, Royal Institute of Public Health, Bilthoven, The Netherlands.
3. Kimbrough et al. 1983. Health implications of 2,3,7,8-Tetrachloro dibenzodioxin (TCDD) contamination of residential soil. Atlanta, Center for Environmental Health, Center for Disease Control.
4. Kim, N.K. and J. Hawley. 1984. Revised risk assessment: Binghamton State Office Building. Albany, Bureau of Toxic Substance Assessment, New York State Department of Health.

Several agencies, including The U.S. Environmental Protection Agency (USEPA), Centers for Disease Control (CDC), New York State Department of Health (NYSDOH) and the National Research Center of Canada (NRCC) have published excess carcinogenic risk estimates for 2,3,7,8-TCDD. The basis for these risk estimates include the two year rat feeding study published by Kociba et al. (1978), with an independent pathology review performed by Squires and an NCI study using rats and mice. A carcinogenic risk estimate for a mixture of HCDD isomers has also been published by EPA, based on one NCI study in rats and mice (USEPA, 1984b).

The carcinogenic risk estimates published by these agencies, using essentially the same data bases, vary over three orders of magnitude as shown in Table 5-2. This data are presented in terms of the estimated quantity of 2,3,7,8-TCDD or HCDD in fg/kg of body weight which, if consumed each day over a 70 year lifetime, would cause one increased case of cancer for every one million people exposed to that concentration.

There are several factors that account for differences in the risk estimates. First, extrapolations from animals to humans can be done on the basis of either relative weights or surface areas. The latter approach may more closely approximate human pharmacological responses. However, it is not clear which of the two approaches is more appropriate for carcinogens. In the absence of information on this point, it seems appropriate to apply the most generally used and more conservative method. In the case of TCDD studies, the use of extrapolation based on surface area rather than weight increases the unit risk estimates by a factor of 5.8 for rats and about 13 for mice (Bayard, 1984).

Second, extrapolations can be performed by using the most sensitive responders or by averaging responses of all adequately tested bioassays. Similarly, these extrapolations can be performed by either grouping different lesion sites to average the risk, or by fitting the tumor evidence data from each lesion site. This last procedure can suggest the most sensitive risk levels and target organs (OSTP, 1984). The CDC fitted separately, the tumor data for each lesion site thereby providing for a range of extrapolated risk estimates.

TABLE 5-2

Extrapolated Human-Equivalent Dose/Response Data to Estimate An Upper Bound To Carcinogenic Risk*

PCDD Isomer	Agency	10^{-6} cancer risk	Method Used To Extrapolate Risk
2,3,7,8,-TCDD	Canada(1)	30-90 fg/kg/day	Linearized Extrapolation and Multi-stage models
	USEPA(2)	6.4 fg/kg/day	Linearized Multi-stage model
	CDC(3)	28-1428 fg/kg/day	Linearized Multi-stage model
	FDA(2)	57 fg/kg/day	Linearized Multi-stage model
HCDD**	USEPA(4)	161 fg/kg/day	Linearized Multi-stage model

*Extrapolated from long-term animal feeding studies. Data are provided as that quantity of PCDD isomer in fg/kg-body weight per day which if ingested over a 70-year lifetime would cause one additional case of cancer for every one million people exposed to that dose.

**Mixture of 1,2,3,6,7,8 and 1,2,3,7,8,9 isomers.

fg = 10^{-15} grams

1) NRCC, 1981

2) USEPA, 1984a

3) Kimbrough, 1983

4) USEPA, 1984b

Third, corrections for high early mortality of animals in the high dose group was used by the EPA to provide an adequate fit of the data to the dose/response extrapolation.

Finally, several different extrapolation models can be used to provide a best fit for the data. Results of the different methods used to calculate the carcinogenic risk are discussed in Table 5-2. It is apparent from this table that the most conservative assessment of carcinogenic risk for 2,3,7,8-TCDD is the risk estimate published by EPA. It should be reiterated that the true shape of the dose/response curve at low doses cannot be determined experimentally (NRC, 1983). Moreover, several extrapolation models fit the data equally well.

In January, 1984, three agencies (EPA, FDA, CDC) met to review the differences in carcinogenic potency estimates. All agreed that correcting for high early mortality is appropriate. The remaining differences were judged to be within the range of uncertainty in the risk assessment process (EPA, 1984). A summary of the different factors used by the various agencies to calculate a 95 percent upper limit unit risk estimate is provided in Table 5.3 (Bayard, 1984). In this context, the EPA extrapolated dose response data, which is the most conservative extrapolation, must be regarded as an upper bound to cancer risk. Actual risk may be significantly lower.

5.2.3. Multiple Components. As noted in Section 2.0, toxicity data required to evaluate risks exists principally for the 2,3,7,8-TCDD isomer, which represents only a small fraction (less than 1%) of the total PCDD emissions predicted from the BNYRRF. The PCDD emissions, in turn, are present in smaller amounts than PCDFs. Therefore, the overall toxicity of the complex mixture of PCDDs and PCDFs predicted in the emission products remains in question. Several approaches have been used to deal with this uncertainty. These approaches were recently reviewed by Barnes (1983) and are described below.

First, all isomers of TCDD can be regarded to be as toxic or carcinogenic as 2,3,7,8-TCDD. This approach is likely to significantly overestimate risks, since the available data suggests that substitution in three or four of the 2,3,7,8-positions influences toxicity significantly (Harding, 1982).

TABLE 5-3

FACTORS USED BY VARIOUS AGENCIES IN CALCULATING THEIR 95% UPPER-LIMIT UNIT RISK ESTIMATES FOR TCDD (From Bayard, 1984)

	FACTOR	EPA	FDA	CDC	Effect of Difference on 95% Upper-Limit Unit Risk Estimate
1.	All used Dow Chemical Co. feeding study on female Sprague-Dawley rats. All used linerized mutli-stage model.	--	--	--	Same factors
2.	Pathologist - Kociba or Squire.	Both	Kociba	Squire	Less than 10%
3.	Adjustment for high early mortality in dose group.	Yes	No	No	Adjustment increases estimate by 1.7 to 2.6 [a]
4.	Selection of tumor types	All Significant tumors	Liver only	Liver only	Less than 10%
5.	Animal-to-man dose equivalence	$\frac{\text{dose}}{\text{surface area}}$	$\frac{\text{dose}}{\text{body weight}}$	Liver concentration	Using administered dose decreases estimate by a factor of 5.38 over the other two.
6.	Dose used for curve fit	Administered	Administered	Liver concentration at terminal sacrifice	Using administered dose decreases estimate by a factor of 2.
7.	95% upper-limit unit risk estimate $(fg/kg/day)^{-1}$	1.56×10^{-7}	1.75×10^{-8}	3.6×10^{-8} (when converted to administered dose)	

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[a] Adjustment increases estimate by factor of about 1.7 if high dose is included in unadjusted analysis; increases estimate by factor of 2.6 if high dose is excluded from unadjusted Squire analysis due to poor fit.

TABLE 5-3 (Continued)

FACTORS USED BY VARIOUS AGENCIES IN CALCULATING THEIR 95% UPPER-LIMIT UNIT RISK ESTIMATES FOR TCDD (From Bayard, 1984)

FACTOR	EPA	FDA	CDC	Effect of Difference on 95% Upper-Limit Unit Risk Estimate
8. Virtual safe dose for upper-limit risk of 10^{-6}; units of fg/kg/day	6.4	57.2	27.6	

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[a] Adjustment increases estimate by factor of about 1.7 if high dose is included in unadjusted analysis; increases estimate by factor of 2.6 if high dose is excluded from unadjusted Squire analysis due to poor fit.

A second approach is to use one of several methods for calculating a toxic equivalent of the complex mixture. For example, the Swiss EPA evaluated the toxicity of the mixture of PCDDs and PCDFs emitted from a resource recovery facility by taking into account the relative ability of the various isomers to induce microsomal enzymes.

The estimation was imprecise, being scaled in order of magnitude. It was conservative in the sense that an entire homologous group was assigned the weighting appropriate for the most potent inducer in that group. These factors were then used as weighting factors to convert the mass of each of the different homologues of PCDDs and PCDFs to 2,3,7,8-TCDD equivalents. Using this approach they estimated total 2,3,7,8-TCDD equivalents to be 60 times the amount of measured 2,3,7,8-TCDD (SFOEA, 1982).

Similarly, Olie has approached the problem by accepting Poland's hypothesis on the toxicity of PCDDs being related to substitution in three or four of the 2, 3, 7, and 8 positions. These congeners were the ones considered to be of concern; the rest were ignored. Olie, then used a method suggested by Grant (1977) to calculate a toxic equivelency factor for a complex mixture of PCDDs and PCDFS. The method assumes a toxicity factor of 1 for 2,3,7,8-TCDD and 0.1 for the other isomers with three and four chlorine atoms in the lateral positions. Further, the method assumes that all isomers are equally distributed in each isomer group. Applying this method, Olie estimated that fly ash and flue gas extracts from a municipal incinerator tested in the Netherlands contained 2,3,7,8-TCDD equivalents equal to 50 and 80 times, respectively, the analyzed amounts of 2,3,7,8-TCDD (Olie, 1980).

A third approach uses bioassay systems to test for 2,3,7,8,-TCDD equivalency. For example, a bioassay method has been developed to investigate the ability of complex mixtures of PCDDs and PCDFS to displace radiolabeled 2,3,7,8-TCDD from a cytosol receptor. Binding to this receptor may be the first step in the mechanism of toxicity. Using this bioassay the estimated amount of 2,3,7,8,-TCDD equivalents in a fly ash extract was found to be about 40 times the actual amount of 2,3,7,8-TCDD found in the sample (Sawyer _et_ _al_., 1983).

Similarly, a bioassay has been developed to test the ability of PCDD and PCDF mixtures to induce the aryl hydrocarbon hydroxylase (AHH) enzyme system. The 2,3,7,8-TCDD isomer is a potent inducer of this enzyme system. This induction is thought to result from formation and transport of the 2,3,7,8-TCDD/cytosol receptor complex to the cell nucleus. Use of two different techniques for measuring the AHH induction indicated that a fly ash extract was 8 and 26 times stronger an inducer for the 2,3,7,8-TCDD equivalents as compared to the 2,3,7,8-TCDD (Sawyer et al., 1983).

An acute toxicity bioassay was performed by the New York Department of Health. The NYSDOH took PCDD- and PCDF-containing material released during a transformer fire in an office building and found that it behaved in their bioassay systems with about 50 times the potency expected from the 2,3,7, 8-TCDD content alone (Eadon, 1982).

As described above and as summarized by Barnes, using different bioassay systems and different methods the toxic equivalency of complex mixtures of PCDDs at PCDFs was estimated to vary within an order of magnitude. Values ranged from 8 to 80 times greater than the toxicity due strictly to the 2,3,7,8-TCDD concentration (Barnes, 1983).

For the purposes of risk assessment, we used one of these techniques to estimate the toxicity of the complex mixture of PCDDs and PCDFs predicted in BNYRRF emissions. We selected an approach used by the Swiss EPA to calculate a toxic equivalency of the multiple components equal to 59 times the toxicity of 2,3,7,8-TCDD alone (SFOEP, 1982). The basis for these calculations is presented in Table 5-4. The reason for selecting this Swiss approach is that it readily provides a mechanism for estimating the relative toxicity of complex mixtures containing differing ratios of PCDD and PCDF homologues. The method was modified somewhat because the Swiss EPA approach did not address the weighting factor of TriCDDs or TriCDFs. Based upon the limited experiments with 2,3,7,TRI-CDD reported by NRCC, however, the relative toxicity and enzyme induction capacity of the TRI-CDDs are at least three orders of magnitude less than 2,3,7,8-TCDD. Based on this data, a weighting factor of .01 was applied as the appropriate weighting factor for the TRI-CDDs and TRI-CDFs.

TABLE 5-4

CALCULATION OF TOXIC EQUIVALENTS
BROOKLYN NAVY YARD FACILITY

	Concentration in Flue Gas (ng/Nm^{3++})	Relative Toxicity	Toxic Equivalent Concentration
Tri-CDF	307.4	.01*	3.07
Tetra-CDF	92.2	.1	9.22
Penta-CDF	26.6	.1	2.67
Hexa-CDF	63.5	.1	6.35
Hepta-CDF	7.7	.01	0.08
Octa-CDF	0.6	0	0.0
Tri-CDD	13.3	.01*	0.13
Tetra-CDD	6.5	.01	0.06
Penta-CDD	10.7	.1	1.07
Hexa-CDD	16.4	.1	1.64
Hepta-CDD	7.8	.01	0.08
Octa-CDD	2.6	0	0.0
2,3,7,8 TCDD	0.42	1	0.42
Total			24.79

$$\frac{[\text{Total Toxic Equivalent}]}{[2,\ 3,\ 7,\ 8\text{-TCDD}]} = \frac{24.79}{0.42} = 59$$

* Relative Toxicity for Tri-CDD and Tri-CDF assumed based on 3000 fold difference in enzyme induction and 30,000 fold difference in acute toxicity (NRCC, 1982).

** From Table 3-2

It should be stressed that the selection of a toxic equivalency factor of 59 is somewhat arbitrary. The data base is too limited to provide experimentally determined (i.e. bioassays) upper and lower limits to toxic equivelency for incinerator emissions.

Furthermore, calculations of toxic equivalency on the basis of various assumptions regarding the toxicity of isomers containing chlorine in 3 or 4 of the lateral ring positions should be examined critically. The data are quite complex regarding the biological activity of each of the isomers, which can vary widely (Sawyer, 1983).

Nonetheless, in accordance with procedures used in risk assessment, we related a factor that provides an estimated upper limit for predicting toxic equivalency.

A toxic equivalency of 59 is believed to be reasonable on the basis of the limited experiments using fly ash or soot in animal feeding or enzyme bioassy experiments (Sawyer et al., 1983; Eadon, 1982). As discussed previously, toxic equivalencies less than 60 were observed in these experiments.

In order to address the multiple components problem, we will assess risks due to PCDD and PCDF emissions from the BNYRRF using three different models. The first model will assume that exposure to 2,3,7,8-TCDD constitutes the only significant PCDD related risk. The second model will assume that all the TCDDs (tetras) are as toxic as 2,3,7,8-TCDD. The third model will use the Swiss approach to calculate a toxic equivalency of the multiple components equal to 59 times the toxicity of 2,3,7,8,-TCDD alone.

5.3 Current Standards and Guidelines

As part of the risk assessment, the daily intake levels or exposure levels were compared with applicable standards and guidelines. These include the following.

5.3.1 EPA Risk Assessment for Municipal Waste Combustors (MWC's). EPA has issued a risk assessment on the dioxin related risks for 5 different MWC's (USEPA 1981). The agency presented data showing that the average annual ground level concentrations of TCDD, using the PTMAX air dispersion model, ranged up to 3.8 x 10^{-5} ng/m^3 for 2, 3, 7, 8-TCDD and up to 9.2 x 10^{-5} ng/m^3 for total TCDDs.

With this exposure data, EPA used 5 different mathematical models to determine an upper bound for cancer risk. This data and the assumptions are shown in Tables 5-5 and 5-6. The calculations use the conservative assumption that all TCDDs are as carcinogenic as 2, 3, 7, 8-TCDD. EPA found that the increased cancer risks ranged from 8 to 19 x 10^{-6} depending upon the risk extrapolation model used. On the basis of these results, EPA concluded that the risks to public health from these MWC's was minimal.

Recently, EPA performed a risk assessment at a sixth MWC (USEPA, 1983). Higher TCDD emission levels were detected at the facility than had been reported in the earlier assessment. These higher levels were attributed to the failure of the operator to adhere to the design requirements of the facility. The operator was feeding municipal waste to the incinerator at a rate significally above its design capacity. The operator has since modified his procedure, and the facility will be retested.

Nonetheless, using the assumptions and modeling techniques described in Tables 5-5 and 5-6, EPA found that the extrapolated upper bound to the increased cancer risks was calculated as 4.6 x 10^{-5} for the sixth facility. Although the estimated risks were nearly six times higher than for the earlier MWC study, EPA concluded that, "...in light of...the conservative assumptions...the steps being taken to ameliorate this situation...the Agency does not believe that this most recently completed MWC represents a significant health concern..." (USEPA, 1983).

5.3.2 NYSDEC Ambient Air Guideline. NYSDEC established an annual average ambient air concentration at ground level of 9.2 x 10^{-5} ng/m^3 TCDD as a performance guideline in evaluating the issuance of permits for combustion facilities. This guideline is primarily based on EPA's evaluation

TABLE 5-5

RANGE OF MAXIMUM AVERAGE ANNUAL GROUND LEVEL CONCENTRATIONS OF TCDD ISOMERS USING PTMAX AIR DISPERSION MODEL[a]

Pollutant(s)	Range (ng/m^3)
2,3,7,8-TCDD	up to 3.8×10^{-5}
Total TCDDs	up to 9.2×10^{-5}

TABLE 5-6

RANGE OF UPPER BOUNDS[a] OF TCDD CARCINOGENIC RISKS DERIVED FROM VARIOUS EXTRAPOLATION MODELS

Mathematical Model	Upper Bound of Cancer Risk
Linearized Multi-stage	up to 8×10^{-6}
Probit	up to 15×10^{-6}
Logit	up to 15×10^{-6}
Weibull	up to 14×10^{-6}
Gamma Multi-hit	up to 19×10^{-6}

a - Upper bound of the 95% confidence interval for this bioassay.
(Barnes, 1983)

ASSUMPTIONS

1. The carcinogenic properties and reproductive effects of all TCDDs are the same as that of 2,3,7,8-TCDD.
2. The PTMAX air dispersion model adequately represents the transport of the emissions to ground level.
3. The composition of emission products found at ground level is identical to the composition (but not the concentration) found in the stack.
4. Seventy-five percent of the inhaled emission particles (to which the TCDDs are generally attached) are retained in the body.
5. All the TCDDs that are retained in the body are biologically available to the organism.
6. The population is exposed to the maximum annual average ground level concentration from the source for 24 hours a day throughout a 70 year lifetime.
7. Humans are of comparable sensitivity as the animals tested.

of TCDD emissions from five municipal waste combustors (See 5.3.1) in which EPA modeled a ground level maximum of up to 9.2×10^{-14} g/m^3 (9.2×10^{-5} ng/m^3) for the MWC producing the highest output of TCDD. EPA concluded that, if this maximum value was not greatly exceeded, TCDD emissions from resource recovery facilities should not pose a concern to public health.

5.3.3 Canadian Ambient Air Quality Provisional Guideline for Chlorinated Dibenzodioxins and Dibenzofurans. In 1982, the Ontario Ministry of the Environment issued ambient air quality guidelines for dioxins and furans (Harding 1982). The guideline includes two key elements. The first is a guideline for an average annual ambient air concentration limit for 2,3,7,8-TCDD. The second is a guideline for mixtures of PCDDs and PCDFs. These guidelines are as follows:

- an annual average ambient air guideline for 2, 3, 7, 8-TCDD of 30 pg/m^3,
- an ambient air guideline for a mixture of chlorinated dibenzo-p-dioxins and chlorinated dibenzofurans. This guideline should not exceed unity in the sum of the fractions for each group as shown below.

$$\frac{x}{30 \text{ pg/m}^3} + \frac{y}{30 \text{ pg/m}^3 \times 50} = 1$$

x = ambient concentration of all CDD's.
y = ambient concentration of all CDF's.

The above equation incorporates an additional safety factor by considering all the congeners in each group as being equal in toxicity to the most toxic congener of the group. The guideline (and the equation) assume that the PCDFs are, on the average, 50 times less toxic than PCDDs.

Harding (1982) suggests that a more realistic formula would correct for the less toxic congeners as follows:

$$\frac{X_{toxic}}{30\ pg/m^3} + \frac{X_{less\text{-}toxic}}{30\ pg/m^3 x100} + \frac{Y_{toxic}}{30\ pg/m^3 x50} + \frac{Y_{less\text{-}toxic}}{30\ pg/m^3 x50x100} = 1$$

Subscript toxic = those congeners have 1 hydrogen atom in the molecule and at least three chlorine atoms in the lateral ring position

Subscript less-toxic = The remaining congeners

5.3.4 The Netherlands Dioxin Standard. In 1982, the Royal Institute of Public Health in the Netherlands issued an acceptable daily intake standard for 2,3,7,8-TCDD of $4x10^{-12}$ grams/kg-b.w/day (Heigden, 1982). This level utilizes the NOEL of 0.001 ug/kg/day (Kociba et. al., 1978) to calculate an ADI which, when divided by a safety factor of 250, constitutes the exposure standard. Although there is no ambient air standard in the Netherlands, applying the assumptions used by Canada (60 kg b.w., $20m^3$ daily ventilation rate and 100 percent respiratory absorption) yields an average annual value of $12x10^{-12}$g TCDD/m^3 as an ambient air standard.

5.3.5 New York State Department of Health Risk Assessment. After a transformer fire in an office building released PCDDs and PCDFs (the building was evacuated and shut down), criteria were developed to allow re-entry into the building (Kim et al, 1984). The guidelines were based upon a NOEL of 1 ng/kg-day divided by a safety factor of 500. This yielded an ADI for calculating reentry levels equal to 2pg/kg-day. Based on this ADI, an air guideline of 15pg/m^3 was established for TCDD toxic equivalents for a 50kg office worker assuming a breathing volume of $10m^3$ for an 8 hour day, 250 day work year as shown below.

$$\frac{2pg/kg\text{-}day \times 50kg}{10m3} \times \frac{365}{250} = 15pg/m^3 \text{ TCDD Toxic Equivalents}$$

In a similar fashion, guidelines for contamination of work surfaces were established, based on assumptions made regarding ingestion and dermal absorption pathways. These assumptions included:

1. Surface contact is assumed to result in the complete transfer of contaminants to the skin (as measured by a wipe test).

2. Total body surface area in square meters (S) can be estimated from a person's height in centimeters (H) and weight in kilograms (W). Data from the National Center for Health Statistics indicate that the height of a 50 kilogram female averages about 154 centimeters. [DuBois et al., 1916; Ganong, 1975; Guyton, 1976]

   $S=0.007184 \times W^{0.425} \times H^{0.725}$ $S=0.007184 \times 50^{0.425} \times 154^{0.725}$
   Total surface area is 1.46 m^2

3. The hands account for approximately 4.5% of the total surface area.

   $1.46\ m^2 \times .045 = 0.0657\ m^2$

4. The contaminants from 5%, 10% or 25% of the surface area of the hands is assumed to be ingested every day.

   $0.0657\ m^2 \times 0.05 = 0.0033\ m^2$ $0.0657\ m^2 \times 0.10 = 0.0066\ m^2$
   $0.0657\ m^2 \times 0.25 = 0.016\ m^2$

5. The maximum exposed surface area for considering dermal absorption is the entire area of both arms. That surface area for a 50 kilogram female is 19% of the total body surface area, or 0.28 m^2 ($0.19 \times 1.46\ m^2$) [Diem et al., 1970]. Contact between skin and contaminated walls (or other surface) is assumed to occur for 10%, 25% or 50% of this surface area.

   $0.10 \times 0.28\ m^2 = 0.028\ m^2$ $0.25 \times 0.28\ m^2 = 0.070\ m^2$ $0.50 \times 0.28\ m^2 = 0.14\ m^2$

6. The amount of contamination absorbed by the skin is assumed to be 1% or 10% of the contaminant on the skin surface [Poiger et at., 1980].

7. The maximum and minimum guidelines among all possible guidelines were calculated as shown below.

   a. Maximum guideline

   Assumptions - ingest contamination from 5% of the hands' surface area (0.0033 m^2)

   - absorb 1% of the contamination with 10% of the surface area of the arms contacting a contaminated surface (0.00028 m^2)

   100 picograms/(0.0033 m^2 + 0.00028 m^2) = 28 ng/m^2

   b. Minimum guideline

   Assumptions - ingest contamination from 25% of the hands' surface area (0.016 m^2).

   - absorb 10% of the contamination with 50% of the surface area of the arms contacting a contaminated surface (0.014 m^2).

   100 picogram/(0.016 m^2 + 0.014 m^2) = 3.3 ng/m^2

5.4 Comparison of the Annual Average Ambient Air Concentrations of PCDDs and PCDFs at the Point of Maximum Impact with Standards and Criteria.

As the first criteria of risk, the average annual ambient air concentrations of PCDDs and PCDFs at the point of maximum impact were compared with existing standards and criteria. The purpose of this comparison was to determine if the predicted maximum annual average concentrations of PCDDs and PCDFs resulting from the operation of the BNYRRF exceed any existing standards or criteria at any point downwind of the facility.

As described in Section 4.2, the maximum ambient air concentrations of PCDDs and PCDFs are predicted to occur in Case 1, where we have assumed that all PCDDs and PCDFs are emitted in a gaseous state. Maximum average annual concentrations of PCDDs and PCDFs at ground level and elevated receptors used in the following comparisons are provided in Table 4-1.

5.4.1 Comparison with Canadian Standard. In 1982, the Ontario Ministry of the environment issued ambient air quality guidelines for complex mixtures of PCDDs and PCDFs using the ADI/NOEL approach as described in Section 5.2.1. This guideline stated that the following equation should not exceed 1.

$$\frac{X}{30pg/m^3} + \frac{y}{30pg/m^3 x50} = 1$$

x = Total PCDD concentration
y = Total PCDF concentration

Table 4-1 provides the predicted annual average PCDD and PCDF concentrations at ground level. Applying these numbers to the Ontario guidelines gives us:

$$\frac{0.23pg/m^3}{30pg/m^3} + \frac{1.99pg/m^3}{30pg/m^3 x50} = .009$$

The predicted worst-case downwind ambient concentration for PCDDs + PCDFs equals 0.9% of the standard. This standard is conservative in that all PCDD's are treated as being as toxic as 2, 3, 7, 8 TCDD and all PCDFs are treated as being 1/50 as toxic as 2, 3, 7, 8 TCDD.

5.4.2 Comparison with Netherlands Standard. The Netherlands has issued a standard for 2,3,7,8-TCDD based upon an ADI of 4 x 10^{-12} g/kg of b.w.-day. Applying assumptions used by Canada (60 kg/man, 20 m^3 daily ventilation rate, a 100% particulate retention and 100% bioavailability) yields a maximum daily acceptable ambient air concentration of 12 pg/m^3 of 2,3,7,8-TCDD.

The predicted maximum average annual concentration of 2,3,7,8-TCDD at ground and elevated receptors of 0.00168 pg/m^3 equals 0.014% of the Netherlands standard. Using a toxic equivalency factor of 59, the levels of TCDD toxic equivalents are still only 0.83% of the Netherlands ADI.

5.4.3 Comparison with NYSDEC Guideline. NYSDEC used the EPA's Risk Assessment of the Municipal Waste Combustors (MWCs) to establish a performance guideline for evaluating other combustion sources. As described in Section 5.3.1, EPA found a maximum annual average ambient air concentration at ground level equal to 9.2×10^{-14} g/m^3 for all T_4CDDs. EPA performed a risk assessment based on these concentrations and stated that the excess cancer risks (which ranged up to 19×10^{-6}) presented no significant risk to the public. On the basis of EPA's risk assessment, the maximum PCDD level found was then adopted by NYSDEC as a guidance level. Using data from Table 4-1, the maximum average TCDD concentrations predicted in the ambient air downwind of the BNYRRF at ground level and elevated receptors is 0.026 pg/m^3 which is equal to 28.2% of the NYSDEC guideline for total TCDDs.

5.4.4 NYSDOH Guideline. NYSDOH established air and exposure guidelines for reentry into a Binghamton, New York, office building that had been evacuated following an electrical transformer fire. For workers exposed for 250 days/year, 8 hour/day, the TCDD toxic equivalent concentration should not exceed 15 pg/m^3. This concentration adjusted for 24 hour/day exposure for 365 days per year equals 3.4 pg/m^3. Based upon our air dispersion model (Table 4-1) we predict an average annual 2,3,7,8-TCDD ambient air concentration at ground level equal to .00168 pg/m^3 which is equal to a total TCDD toxic equivalent concentration of .099 pg/m^3. Therefore, the predicted emissions from the BNYRRF are expected to result in an annual average ambient air concentration of 2,3,7,8-TCDD and TCDD toxic equivalents that is only 0.049% and 2.9% of the NYSDOH guideline, respectively.

5.5 Computation of a "Worst-Case" Upper Bound to the Level of Risk Associated with Emissions from the BNYRRF.

In the previous section, the maximum annual average PCDD and PCDF concentrations at ground level and elevated receptors were compared to the existing standards and criteria. In this section, we calculated a range and upper-bound limit of risk for each of three potential pathways for PCDD and PCDF exposure: inhalation, ingestion, and dermal absorption.

An upper-bound limit of risk is a predicted upper limit or maximum risk, using worst-case assumptions, at the point of maximum exposure, for a period of a 70-year lifetime.

To calculate a range and upper-bound limit of risk, we have estimated a PCDD and PCDF daily intake for each of the three pathways using the dispersion and deposition models for dioxin emissions presented in Chapter 4, and data regarding the uptake and bioavailability of PCDDs and PCDFs from air, soil, dust, and street dirt. The PCDD daily intake was then compared with existing ADIs and the cancer dose/response data to determine if there are significant health impacts that might be associated with the predicted BNYRRF emissions.

5.5.1. General Approach. In order to lessen the inherent degree of uncertainty in the risk assessment process, the following sequence was followed.

1. The compounds considered were initially limited to 2,3,7,8-TCDD and HCDD. Although other isomers are present, these compounds are the only ones with enough toxicity and carcinogenicity data to apply to a risk assessment using standard procedures for estimating carcinogenic and other risks in human populations.

2. Risks associated with inhalation of the maximum annual ambient air concentrations of PCDDs and PCDFs, resulting from the predicted operations of the BNYRRF, were evaluated first. This pathway allows for the best estimate of risk with the least degree of uncertainty.

3. Data from air dispersion modeling (see Section 4.0) and assumptions regarding pulmonary uptake of particulates were used to calculate a maximum daily intake of PCDDs and PCDFs by the in-

halation pathway at ground-level and elevated receptors (DI_{inh}). The resulting number was then compared with ADIs and cancer dose/response extrapolations developed by regulatory agencies.

4. Since BNYRRF emissions constitute a mixture of PCDDs and PCDFs, the concept of toxic equivalency, as described in Section 5.2.3, may be an appropriate method for estimating the toxicity of these mixtures. Therefore, a toxic equivalency factor of 59 was applied to produce an estimate of the toxic equivalent daily intake for comparison with ADIs.

5. The daily intake through inhalation (DI_{inh}) was used in conjunction with three different cancer risk extrapolation models to generate an upper bound estimate of the projected excess cancer risk resulting from predicted BNYRRF emissions.

6. Although inhalation is an important route of exposure for emitted particulates, it has been suggested that ingestion of PCDD and PCDF containing particulates deposited on outdoor and indoor surfaces (i.e., on soil, dust and street dirt) might also be risk factors. The sensitivity of the daily intake rate through inhalation to the additional daily intake from ingestion was tested. There is considerably less data to model this pathway and predict steady state concentrations of PCDDs in soil and dust, and to accurately estimate the amount of soil and dust ingested each day. Therefore, the number of assumptions, and hence, the degree of uncertainty of these estimates is increased relative to the inhalation pathway. Due to this uncertainty, a number of conservative assumptions were used to establish an upper bound limit to risk for this pathway.

7. In order to make the assessment as thorough as possible, exposure through the dermal absorption pathway was examined. Again, information regarding the mechanism of dermal toxicity and absorption is limited and conservative assumptions were used to estimate risk.

5.5.2. General Assumptions

Several general assumptions are used throughout the assessment.

1. The air dispersion and particulate deposition modeling of the stack emissions from the chimney adequately represents the transport of the PCDD emissions to ground level.

2. The composition of emission products found at ground level is identical to the composition (but not the concentration) found in the stack.

3. The population is exposed to the maximum annual average ground level concentrations from the incinerator for 24 hours a day throughout a 70-year lifetime.

4. We have assumed conservatively, that there is no loss of PCDDs through volatilization or photodegradation.

5.5.3 Inhalation Exposure

5.5.3.1 Calculation of Daily Intake. In order to calculate an upper-bound estimate of the daily intake from inhalation, the average maximum annual ambient air concentration of 2,3,7,8-TCDD must be multiplied by the average amount of air exchanged per day, the particulate retention rate and the bioavailability of the inhaled material. Thus, the maximum daily intake of 2,3,7,8-TCDD through inhalation (DI_{inh}) in grams per day is calculated as shown below:

$$DI_{inh}\ (\text{g/day}) = \text{TCDDs}\ (\text{g/m}^3) \times \text{ventilation rate}\ (\text{m}^3\text{/day}) \times \text{particulate retention}\ (\%) \times \text{bioavailability}\ (\%).$$

In the absence of quantitative data, a conservative assumption has been applied, that indoor ambient air contaminant concentrations equal outdoor concentrations. In fact, as reviewed by Yocum, this is not true for contaminants of outdoor origin (Yocum, 1982). For contaminants attached to particulates, the long-term indoor versus outdoor concentration is reduced by the scrubbing of outdoor air as it penetrates the building shell. The degree of reduction is in turn dependent on the season of the year, with higher indoor concentrations reported during warm weather, when windows are kept open. For contaminants such as lead or nonmethane hydrocarbons, the indoor concentration may equal only 50 - 66% of the outdoor concentration. Since the average person spends at least 1/3-1/2 of his or her life indoors, the assumption that the indoor/outdoor concentrations are equal may overestimate risk by at least 11-17%.

Reported air exchange volumes (averages for adult men and women combined) range from $13m^3$ up to $20m^3$. For this assessment, the estimate used by the CDC of $15m^3$/day will be used since this represents a reasonable estimate for a population that includes children in addition to working adults.

Not all particulate matter inhaled into the lungs is retained by the lungs. Thus, the amount of exposure depends on the particle size distribution. We used an EPA estimate that 75% of the inhaled particulates are retained (EPA 1981). This estimate is based upon studies done by the International Commission of Radiological Protection. It appears to be a slightly conservative estimate in that 50% of the particles by weight are of the size category (less than 2um) expected to settle deeply into the lungs (Lippman, 1979). The remaining 50% will be deposited in the upper respiratory tract and subsequently swallowed.

No data are available regarding the bioavailability of PCDDs and PCDFs in laboratory animals subjected to PCDD dosing through inhalation exposure. In the absence of any bioavailability data for the inhalation pathway, and in accordance with the EPA methodology used in its risk assessment of five MWC's, a conservative assumption of 100% bioavailability was used.

To derive an upper limit to DI_{inh}, we assumed a maximum annual average concentration of 2,3,7,8-TCDD for ground and elevated receptors equal to 0.00168 pg/m^3. This concentration was obtained from Table 4-1 using the Case 1 scenario where, for the purpose of modeling, it was assumed that all PCDD emissions leave the stack in a gaseous state.

To summarize, in order to determine an upper bound maximum daily intake of 2,3,7,8-TCDD from the inhalation pathway (DI_{inh}), the following assumptions were made:

- 75% of the inhaled particles are retained by the body
- 15 m^3 of air are exchanged in one day
- 100% of the inhaled particles are bioavailable
- Maximum ambient air concentration of 2,3,7,8-TCDD equals 0.00168 pg/m^3

$$DI_{inh} = 0.00168\ pg/m^3 \times 10^{-12}\ g/pg \times 0.75 \times 15\ m^3/day$$

$$DI_{inh} = 1.9 \times 10^{-14}\ g/day \text{ for ground or elevated receptor}$$

For the Case 2 scenario, $DI_{inh} = 8.8 \times 10^{-15}$ g/day (assumes ambient air concentration of 2,3,7,8-TCDD = 0.000782 pg/m^3)

5.5.3.2 Comparison of Daily Intake from Inhalation with Acceptable Daily Intake Levels (ADIs). Several regulatory agencies in this country and abroad have set 2,3,7,8-TCDD standards and criteria on the basis of an acceptable daily intake as presented in Table 5-1. These agencies felt that the ADI approach was a reasonable method for determining very safe dose levels. It also provides a large margin of safety for non-carcinogenic toxic effects.

The upper bound estimate of 2,3,7,8-TCDD intake through the inhalation pathway in comparison with these ADIs is presented in Table 5-7. In comparison to these ADIs, the impact of the BNYRRF emissions are negligible. For example, the maximum estimated intake of 2,3,7,8-TCDD through the inhalation pathway for a 70 kg man is only .017% of the most conservative published ADI, of 1.8 pg/kg-day.

As an added safety factor, we compared the daily intake with published ADIs using two other conservative assumptions. First, that all TCDDs (tetra chlorinated species) were as toxic as the 2,3,7,8-TCDD. Second, that the

TABLE 5-7

Upperbound Estimated Percentage of Acceptable Daily Intake (ADI) Attributable To Inhalation of PCDD and PCDF Emissions from the BNYRRF at Ground Level and Elevated Receptors

		cceptable Daily Intake (ADI)		
	Canada 10 pg/kg-day	Netherlands 4pg/kg-day	NYSDOH 2pg/kg-day	CDC 1.8pg/kg-day
Upperbound Daily Intake-Inhalation Pathway				
2,3,7,8-TCDD(a) (2.7 x 10^{-4}pg/kg-day)	0.0027%	0.007%	0.014%	0.01%
TCDD(b) (4.2 x 10^{-3}pg/kg-day)	0.042%	0.11%	0.21%	0.23%
TCDD Toxic Equivalency(c) (1.6 x 10^{-2} pg/kg-day)	0.16%	0.40%	0.80%	0.89%

* Assumes 70 kg/person inhaling .00168 pg/m^3 of 2,3,7,8-TCDD

(a) DI_{inh} (pg/kg-day) = DI_{inh} (g/day)/70kg = 1.9 x 10^{-2} pg/day/70 = 2.7 x 10^{-4} g/day

(b) DI_{inh} (TCDD) = DI_{inh} (2,3,7,8-TCDD x 15.5)

(c) DI_{inh} (Toxic Equivalents) = DI_{inh} (2,3,7,8-TCDD x 59) toxicity of the complex mixture of PCDDs and PCDFs was 59 times that of 2,3,7,8-TCDD alone, using the toxic equivalency approach.

As can be seen in Table 5-7, even with these assumptions, the maximum daily intake of TCDD toxic equivalents through inhalation of gaseous or particulate emissions from the BNYRRF ranges from 0.16 to 0.89% of the various ADI's. These levels are well below very safe dose levels suggested by these regulatory agencies. Similar low levels are observed, using the assumption that all tetra CDDs are as toxic as 2,3,7,8-TCDD. The data indicates that risks associated with potential non-carcinogenic toxic effects due to inhalation of PCDD and PCDF emissions from the BNYRRF are not significant.

5.5.3.3 Comparison of Daily Intake From the Inhalation Pathway With Cancer Risk Estimates. A primary focus of concern regarding dioxin emissions from the BNYRRF has been the carcinogenicity risks. Extrapolated dose/response data necessary to estimate carcinogenicity risk is available from long-term animal feeding studies only for 2,3,7, 8-TCDD and a mixture of two HCDD isomers. Using the daily intake calculations for inhalation exposure, and three different risk extrapolation models, an estimate of the excess cancer risk resulting from the projected operations of the BYNRRF was calculated and is presented in Table 5-8. The data presented in this table provides the estimate of the increased cancer incidences per 1,000,000 people exposed (to the maximum concentrations) over a 70-year lifetime.

To calculate these risks, the daily intake (pg/day) for 2,3,7,8 TCDD and HCDDs in a 70 kg/person was compared to the dose (pg/day) required to produce an increase of 1 case of cancer per 1,000,000 people exposed to that dose over a 70 year lifetime.

For example, Table 5-8 indicates that the EPA dose/response extrapolation for 2,3,7,8-TCDD projects a 1 x 10^{-6} excess cancer risk if .0064 pg per kg of body weight is ingested each day over a 70-year period.

A 1 X 10^{-6} excess cancer risk means that the dose response extrapolation predicts one increased case of cancer for every one million (10^{6}) persons exposed to the .0064 pg/kg over a 70-year lifetime.

TABLE 5-8

UPPERBOUND ESTIMATED INCREASED CANCER RISK FOR POPULATION OF ONE MILLION PEOPLE EXPOSED FOR A 70 YEAR PERIOD TO THE MAXIMUM DAILY INTAKE

	Kimbrough[a]	Dose for 1 x 10^{-6} Excess Cancer Risk Kimbrough	EPA
	(1.4 pg/kg-day)	(.028 pg/kg-day)	(.0064 pg/kg-day)
	Upper Bound Excess Risk for 70Kg man		
Daily Intake			
1.9 x 10^{-2} pg/day (2,3,7,8-TCDD)	.0019	.010	.042
0.15 pg/day** (1,2,3,6,7,8 and 1,2,3,7,8,9-HCDD)	---	---	.013

** Dose for 10^{-6} excess risk HCDD (1,2,3,6,7,8 and 1,2,3,7,8,9) = 0.16 pg/kg-day.

Assumes only 20% of total HCDD isomers are 1,2,3,6,7,8 and 1,2,3,7,8,9-HCDD ($DI_{HCDD} = DI_{ing}$ (2,3,7,8-TCDD) x 39.5 x 0.2 = 0.13 pg/day).

a. Differences in Kimbrough dose/response estimates based upon upper and lower confidence limits to risk estimates for different lesion sites.

To quantify the excess cancer risk projected for the BNYRRF, we take a ratio of the predicted daily intake (dose) of 2,3,7,8-TCDD (DI_{inh}) to the dose predicted by a given dose/response extrapolation to cause an excess risk of 1×10^{-6} in a 70 kg person as follows:

$$\text{excess risk} = \frac{DI_{inh}\ (\text{pg/day}) \div 70\ (\text{kg}) \times (1 \times 10\text{-}6\ \text{risk})}{(\text{dose for } 1 \times 10^{-6} \text{ risk in pg/kg-day})}$$

Using the EPA dose/response extrapolation for 2,3,7,8-TCDD cancer risk, and using $DI_{inh} = 1.9 \times 10^{-2}$ pg/day:

$$\text{excess risk} = \frac{1.9 \times 10^{-2}\ \text{pg/day} \div 70\ (\text{kg}) \times (1 \times 10^{-6})}{(.0064\ \text{pg/kg-day})} = .042 \times 10^{-6}$$

Therefore, the EPA dose/response model predicts that the inhalation of 1.9×10^{-2} pg/day of 2,3,7,8-TCDD results in an upper limit to risk equal to less than 0.042 increased cancer cases for every one million people exposed.

For HCDD, only two isomers (1,2,3,6,7,8 and 1,2,3,7,8,9-HCDD) have been tested as a mixture. These compounds were shown to be carcinogenic in animal feeding studies. These two isomers make up only 20% of the total number of possible HCDD isomers. We assumed equal distribution of the various HCDD isomers in particulate emissions. Therefore, the daily intake for the carcinogenic isomers of HCDD was calculated by multiplying the total HCDD intake by 20%. Since DI_{inh}(HCDD) $= DI_{inh}$ (2,3,7,8-TCDD) × 39., DI_{inh} (HCDD) (1,2,3,6,7,8 and 1,2,3, 7,8,9) equals 1.9×10^{-2} pg/day × 39.5 × 0.2 = 0.15 pg/day.

As demonstrated in Table 5-8, the increased cancer risks vary by several orders of magnitude depending upon the risk extrapolation model used. Using the most conservative model, the EPA risk model, and assuming that the excess risks from TCDD and HCDD are additive, the projected levels of exposure under worst case assumptions would not result in more than 0.06 new cases of cancer in a population of one million, exposed to the estimated maximum levels and assuming a maximum daily intake over a 70-year lifetime. In more common terminology, the excess cancer risk for a 70-year lifetime is less than 0.06×10^{-6} or 6 in 100 million. If the other dose extrapolations are more representative, it can be seen that the cancer risk levels are substantially less by one to three orders of magnitude.

Note that the figures in Table 5-6 are not predictions of actual risk. Instead, they denote a level of risk that the actual risk is not likely to exceed, hence the term "upper bound". The actual risk should fall somewhere between zero and the estimated upper bound.

To summarize, the data indicate that the upper-bound excess cancer risks resulting from lifetime inhalation of the maximum annual average ambient air concentrations of 2,3,7,8-TCDD and HCDD, predicted downwind of the BNYRRF, are less than 0.06×10^{-6}. This risk is below levels that represent a significant public health risk.

5.5.3.4. Elevated Receptors As provided in Section 4-2, the air dispersion model used to predict ambient air concentrations of PCDDs and PCDFs predicts that elevated receptors will be exposed to the same average PCDD and PCDF concentrations predicted for ground level receptors. Accordingly, the risks at elevated receptors will be the same as discussed above in the previous section.

5.5.3.5. Summary of Risks Through Inhalation A maximum daily intake for 2,3,7,8-TCDD equal to 1.9×10^{-2} pg/day was predicted for the inhalation pathway. Using ratios of the various homologues, daily intakes for total TCDD, TCDD toxic equivalents, and HCDD were determined.

The level of risk was first estimated by comparing the predicted maximum average annual ambient air concentration of PCDDs and PCDFs with guidelines and standards used by other regulatory agencies.

Comparison of the total PCDD and PCDF concentrations at ground level with the Canadian Standard resulted in a concentration equal to 0.9% of the standard. Similar comparisons with the Netherlands and NYSDOH guidelines yielded .014% and .049% of the guidelines respectively for 2,3,7,8-TCDD, and 0.83% and 2.9% of the guidelines for TCDD toxic equivalents.

Comparison of maximum annual ground level and elevated receptor level TCDD concentrations with a NYSDEC guideline indicates that emissions from the BNYRRF facility will be within 28% of this guideline level.

Despite the application of several conservative assumptions, the daily intake of 2,3,7,8-TCDD through inhalation is predicted to be quite small (less than .017%) in comparison with ADIs promulgated by various regulatory agencies.

As an additional safety factor, the daily intake of TCDD toxic equivalents was determined. Using this toxic equivalency approach, the upper bound risk due to exposure to the mixture of PCDDs and PCDFs equals only 0.89% of the most conservative ADI for 2,3,7,8-TCDD.

An upper bound to carcinogenicity risk was determined using three different cancer dose/response extrapolations. The upper bound excess risk due to exposure to 2,3,7,8-TCDD and HCDD at the point of maximum exposure ranges from less than .0019 to less than 0.055 x 10^{-6}. This equals less than six cases per one hundred million people exposed to the maximum concentration over a 70 year lifetime.

5.5.4 Ingestion and Dermal Exposure.

5.5.4.1 Discussion. The standard practice for most regulatory agencies performing risk assessments for combustion sources is to consider inhalation of emission products as the only pathway of exposure.

Studies performed on other pollutants emitted from point source emissions, such as smelters, or from non point sources indicates that ingestion and dermal absorption of particulate emissions deposited on living area surfaces may also be exposure pathways (USEPA, 1977; USEPA, 1984c). However, typically these pathways are ignored since the data needed to characterize the environmental fate, transport, and biological uptake of toxic contaminants, in relation to ingestion and dermal exposure pathways, are not well documented.

Nonetheless, as an additional safety factor in our own risk assessment, we tested the sensitivity of the risks derived for the inhalation pathway to the additive impacts of ingestion and dermal absorption of dioxin contaminated dust, dirt, and soil.

In Section 4, two emission scenarios were explored. In case 1, it was assumed that all dioxin emissions exit the baghouse in a gaseous state. Under this scenario, deposition of dioxin on streets, homes, parks, etc. is negligible.

In case 2, it was assumed that all dioxins entering the baghouse enter attached to particulates. Those particulates that escape through the baghouse, if heavy enough, will deposit on ground surfaces for potential uptake through ingestion or dermal pathways. However, under this scenario, the maximum annual average ambient air concentrations of PCDDs and PCDFs is decreased compared with case 1. Actual partitioning of dioxins between gaseous and particulate phases will most probably be somewhere between these two extremes presented as cases 1 and 2.

For the purpose of calculating a maximum daily intake of PCDD through maximum ingestion and dermal exposure, the case 2 scenario will be assumed. A daily intake was calculated for these two pathways where:

DI_{ing} = Daily intake of 2,3,7,8-TCDD through ingestion
DI_{derm} = Daily intake of 2,3,7,8-TCDD through dermal absorption.

Determining a daily TCDD intake rate through ingestion is more difficult than determining one for inhalation since the concentrations of PCDD on urban streets and in homes, and the clearing effect of wind, rain, and sunlight cannot be easily modeled. Further, the daily rate of ingestion of soil and dust and the bioavailability is not adequately established in the literature. As a result, in accordance with risk assessment practice, we have used a series of "worst case" assumptions. The daily intake levels calculated using the assumptions should be regarded as upper bound estimates. The actual daily intake is likely to be less than predicted.

5.5.4.2 Daily intake through the ingestion pathway. A daily intake of 2,3,7,8-TCDD through ingestion (DI_{ing}) was estimated in two ways. First, we estimated a rate of soil ingestion in grams per day, TCDD concentration (weight basis) in soil or dirt, and a percentage bioavailability such that:

$$DI_{ing(g/day)} = [\text{TCDD g/g-soil}] \times \text{Daily Ingestion (g/day)} \times \text{Bioavailability}.$$

Using a different, surface area approach, we also determined a concentration of TCDD in g/m^2 on home and street surfaces. Then, using an estimate of bioavailability and the surface contact area for hands, feet and other exposed areas, we calculated DI_{ing} as follows:

$$DI_{ing}(g/day) = [\text{TCDD g/m}^2] \times \text{Surface Contact (m}^2\text{/day)} \times \text{Bioavailability}$$

The CDC, in its risk estimate, made an assumption that the average person ingests from 0.1 to 10 grams of soil a day, depending on the age group. Maximum ingestion rates occur at the 1½ - 3½ year old age group when mouthing behavior is prominent. Using the CDC data, a weighted average ingestion rate for a 70 year lifetime equals 0.41 g/day (Kimbrough, 1983).

The ingestion levels used by CDC seem quite high and therefore conservative when compared with other studies. For example, Duggan and Williams have summarized the literature on the amount of lead ingested through street dust (Duggan _et al._, 1977). In their opinion, a quantity of 50 ug of lead is ingested daily by children. Assuming, on the high side, an average lead concentration in urban environments of 1000 ppm, this would indicate an ingestion of 50 mg/day of soil and dirt per day.

Lepow _et al._, in an assessment of lead exposure in children caused by ingesting dirt and dust, estimated a rate of dirt ingestion equal to 100 mg/day (specifically 10mg of dirt ingested 10 times a day) (Lepow, 1974). In a recent Dutch study, the amount of lead on hands ranged from 4-12ng (Brunekreef, 1983). Assuming maximum lead concentrations of 500 ng/g (the levels were typically lower) and assuming the child ingested the entire contents absorbed on his hand on 10 separate occasions, the amount of ingested dirt would equal 240mg. Thus, to eat 10 grams of soil per day, as suggested by CDC, the child would have to place his hand in his mouth 410 times, a rate which seems improbable. Nevertheless, for calculating soil ingestion rates a range of exposure levels was utilized assuming a daily ingestion rate of 100 mg to 410 mg/day.

Daily intake levels via the ingestion pathway were also calculated using a NYSDOH surface area approach. In their risk assessment of the Binghamton office fire, NYSDOH made the assumption that contaminants contained on 5-25% of the surface area of the hands were ingested. Based upon average hand surface areas for females, the material contained on 0.0033 m^2 - 0.016 m^2 of surface would be ingested each day.

The bioavailability of PCDD contaminated fly ash and soil via ingestion is not well documented. Data on gastrointestinal absorption are provided in Table 5-9. Studies of rats given TCDD in the diet reported 50 to 60 percent absorption. A mixture of TCDD in acetone and corn oil given to rats by gavage resulted in 86 percent absorption. A recent study reported by Mc Connell indicates high bioavailability in guinea pigs and rats fed dioxin contaminated soil from Times Beach (McConnell, 1984).

The CDC uses bioavailability estimates of 30% based on a personal communication from McConnell, who estimated 30-50% bioavailability for PCDD in soil, a level contradicted by his most recent publication (Kimbrough, 1983). Because of the lack of solid information, bioavailability was estimated to range from 30% to 80%.

It should be noted that dioxin is believed to bind more tightly to fly ash than to most soils. Frequently, very difficult extraction techniques are required to desorb the material from fly ash. Therefore, the bioavailability of dioxin adsorbed to fly ash is expected to be lower than for soil.

Feeding of fly ash containing PCDDs to rats over a 19-day period resulted in lower absorbed PCDD levels then for a similar PCDD concentration solvent extracted from fly ash in toluene (Van den Berg, 1983). For example, rats fed fly ash stored PCDDs and PCDFs in their livers at concentrations which were at least 3-5 times lower than rats fed with a comparable amount of a fly ash extract. For Penta-CDD, hexa-CDF, and hexa-CDD isomers, these concentrations were 10-20 times lower. This supports the argument that the bioavailability of fly ash is likely to be on the low side of the

TABLE 5-9

GASTROINTESTINAL ABSORPTION OF 2,3,7,8-TCDD

Species	Vehicle	Dose (ug/kg) Schedule	Percent Absorption Mean ±SD	Reference
Guinea pig	NR	NR Single dose	50	Nolan et al., 1979
Rat	7 ppb in diet	0.5 ug/kg/day x 42 days	50-60	Fries and Marrow, 1975
Rat	20 ppb in diet	1.4 ug/kg/day x 42 days	50-60	Fries and Marrow, 1975
Rat	A:C 1:25	1.0 ug/kg Single dose	84 ±11*	Rose et al., 1976
Rat	A:C 1:25	0.1 or 1.0 ug kg/day, 5 days/ week x 7 weeks	86 ±12*	Rose et al., 1976
Rat	A:C	50.0 ug/kg, Single dose	70	Piper et al., 1973

NR = Not reported
A:C = Acetone:corn oil, v:v

* Mean ± standard deviation

range of numbers generated by feeding extracts of TCDD in acetone and corn oil, or in the diet, as presented in the Table 5-9.

To summarize, a determination of the daily intake due to ingestion was derived on the basis of several different assumptions concerning the patterns of exposure. These assumptions include:

- Ingestion of 100 mg of soil or dust per day and 30% bioavailability
- Ingestion of 410 mg of soil or dust and 30% bioavailability
- Ingestion of 100 mg of soil and 80% bioavailability
- Ingestion of 410 mg of soil and 80% bioavailability
- Contact with surfaces at up to 0.016 m^2/day

Each of these assumptions was tested further by assuming three different sources of exposure - home dust, street dirt, and soil, using the data provided in Section 4.

The concentration of PCDDs in street dirt was determined by dividing the PCDD deposition rate by the average particulate deposition rate from non-dioxin sources. Table 4-4 shows the average annual deposition rate for 2,3,7,8-TCDD equal to .0065 ng/m^2/year. At any point in time, this material is being diluted by 74 g/m^2/year of particulates from non-dioxin sources. Therefore, for the purpose of this assessment, we predict a maximum 2,3,7,8-TCDD concentration to equal 8.8×10^{-14} gram per gram of street dirt (Table 4-6). This is a highly conservative estimate, since the dioxin containing fly ash will be diluted not only by other airborne particulate matter but also by lint, dirt, gravel, etc. The estimates are also particularly conservative in that no degradation, volatilization or physical clearing (e.g. runoff to storm sewers) of TCDD is assumed.

On a weight to weight basis, TCDD concentrations in home dust were assumed to be equal to the concentration in street dirt, an assumption which is used by CDC in its risk assessment and supported by some studies of lead contamination in indoor versus outdoor environments (Harrison, 1979).

The maximum concentration of TCDD's in soils was estimated by assuming a one centimeter mixing zone and estimating a build up over a 20 year period as provided in Table 4-5. Again, the estimate is clearly conservative, with no losses due to volatilization, degradation, or physical clearing.

As discussed in Chapter 4.0, PCDD levels in home dust and street dirt on a surface area basis were also used to estimate risk. The maximum accumulation on floors was estimated assuming indoor deposition at 25% of the outdoor rate, with a 30-day period of accumulation.

There is some evidence to suggest that a 30-day accumulation period is overly conservative. The data provided by Solomon et al.; if extrapolated, indicates that there is from 0.6 to 1g dust/m^2 in single family urban middle class homes (gas heated) in Champagne-Urbana Illinois. His data, if applied to the PCDD and total particulate deposition rates, would indicate that steady state conditions for dust buildup in homes would be reached in three to five days (Solomon, 1977).

For outdoor deposition the accumulation period in urban streets is unknown. The Swiss EPA in their assessment of dioxin emissions from incinerators, used an estimated half life equal to 14 days for rural environments (SFOEP, 1982). Consistent with this Swiss EPA assessment, we have assumed a 30 day period of accumulation as a reasonable accumulation period.

The estimated daily intake through the ingestion pathway calculated on a weight or surface area basis is presented in Tables 5-10 and 5-11.

The maximum estimated daily intake calculated by either method provides reasonably similar results. On a weight basis, the maximum estimated daily intake of 2,3,7,8-TCDD ranged from 2.5×10^{-16}g/day to 2.9×10^{-14}g/day. On a surface area basis, the daily intake ranged from 1.3×10^{-16} to 6.8×10^{-15}g/day.

5.5.4.3 Daily Intake From Dermal Adsorption. Estimating a daily intake due to dermal absorption requires a determination of the surface area or exposed skin, the frequency of contact between the exposed skin and

TABLE 5-10

ESTIMATED DAILY INTAKE OF 2,3,7,8-TCDD THROUGH THE INGESTION PATHWAY

(Weight Approach)

	Source of Exposure		
	Home Dust	Street Dirt	Soil*
Concentration of 2,3,7,8-TCDD	8.8×10^{-14} g/g	8.8×10^{-14} g/g	8.2×10^{-15} g/g
Mechanism		Daily Intake (g/day)	
100 mg/day - 30% Bioavail	2.6×10^{-15}	2.6×10^{-15}	2.5×10^{-16}
100 mg/day - 80% Bioavail	7.0×10^{-15}	7.0×10^{-15}	6.6×10^{-16}
410 mg/day - 30% Bioavail	1.1×10^{-14}	1.1×10^{-14}	1.0×10^{-15}
410 mg/day - 80% Bioavail	2.9×10^{-14}	2.9×10^{-14}	2.7×10^{-15}

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* Assumes 20 year buildup in top centimeter of soil with no loss due to degradation, volatilization or runoff.

TABLE 5-11

ESTIMATED DAILY INTAKE OF 2,3,7,8-TCDD THROUGH THE INGESTION PATHWAY

(Surface Area Approach)

	Source of Exposure	
	Home Dust	Street Dirt
Concentration of 2,3,7,8 TCDD	1.3×10^{-13} g/m^2	5.3×10^{-13} g/m^2
Mechanism	Daily Intake (g/day)	
Contact with .0033 m^2/day - 30% Bioavail	1.3×10^{-16}	5.2×10^{-16}
Contact with 0.0033 m^2/day - 80% Bioavail	3.4×10^{-16}	1.4×10^{-15}
Contact with 0.016 m^2/day - 30% Bioavail	6.2×10^{-16}	2.5×10^{-15}
Contact with 0.016 m^2/day - 80% Bioavail	1.7×10^{-15}	6.8×10^{-15}

---

* Assumes buildup of dust or dirt over 30 day period.

contaminated surfaces, and the rates of absorption for PCDDs and PCDFs bound tightly to soil, dust, and fly ash. Information to calculate these data are also not well documented. Accordingly, a number of assumptions were used to provide a range and upper bound estimate for daily intake through the dermal pathway.

Some estimates of the exposure level due to direct contact can be made by considering the surface area of exposed skin. Based upon this consideration, the CDC has estimated direct contact on a weight basis by assuming contact with up to 0.55 grams of soil per day over a 70-year lifetime. (Kimbrough, 1983).

In its risk assessment of the Binghamton office fire, NYSDOH used a surface area approach and assumed a transfer of surface materials proportional to the surface area of the hands and arms of female workers. Contact between skin and surfaces was then estimated to occur over 10 percent, 25 percent, or 50 percent of this surface area. This estimate resulted in a range of exposures from .028 m^2 to 0.14 m^2 each day (Kim, 1984).

The study by Poiger, et al., (1980), is the only study to provide data on the absorption of TCDD through the skin. Application of TCDD in methanol or TCDD in a soil/water paste resulted in TCDD accumulation in the liver amounting to 2 percent of the administered dose. Application in an activated carbon/ water paste completely eliminated absorption. Dermal application in polyethylene glycol resulted in 9.3 percent absorption compared with oral feeding of TCDD dissolved in ethanol. Since TCDD is expected to be bound tightly to fly ash, the amount of absorption from fly ash may be less than that for soil. As a conservative measure, we have assumed daily absorption rates of 1 percent and 10 percent.

To calculate a daily intake due to dermal absorption we tested the following models:

- contact with 0.55 grams of dust/dirt - 1 percent absorption
- contact with 0.55 grams of dust/dirt - 10 percent absorption
- contact with .028 m^2 of surface area - 1 percent absorption

- contact with .028 m^2 of surface area - 10 percent absorption
- contact with .14 m^2 of surface area - 1 percent absorption
- contact with .14 m^2 of surface area - 10 percent absorption

A daily intake through dermal absorption (DI_{derm}) was calculated as follows:

DI_{derm}(g/day) = [2,3,7,8-TCDD] g/g x 0.55 (weight approach) x g/day x % absorbed

or

DI_{derm}(g/day) = [2,3,7,8,-TCDD] g/m^2 = (surface area approach) x Contact Area m^2/day x % absorbed

The concentration of 2,3,7,8 TCDD in dust, dirt and soil used in the DI_{derm} calculation are the same as those described in Section 5.5.3.2.

The results of the daily intake calculation on a weight basis is presented in Table 5-12. The results using a surface area approach are provided in Table 5-13.

The calculation of a daily intake for dermal absorption using either a weight or surface area approach provides reasonably consistent results. Daily intake of 2,3,7,8-TCDD ranges from 4.5×10^{-17} g/day to 4.8×10^{-15} g/day using the weight approach, and from 3.6×7^{-4} to 6.7×10^{-15} using the surface area approach. Again, a high degree of conservatism has been applied. No losses of TCDD due to volatilization or degradation were considered. No physical clearing rates were considered in the weight approach estimate. Further, a significant rate of absorption was assumed (up to 10%), which for PCDDs bound to fly ash is believed to represent a significant overestimate for dermal absorption.

5.4.4.4 <u>Impacts of Ingestion and Dermal Absorption Pathways on Risk Estimates</u>. Several different models were tested in calculating a daily intake through inhalation, ingestion, and dermal absorption pathways. Using the range of 2,3,7,8-TCDD daily intake estimates provided in Tables 5-9 through 5-13, a minimum and maximum total daily intake in g/day was calculated as shown on Table 5-14 for each of the two emission scenarios (case

TABLE 5-12

DAILY INTAKE FROM DERMAL ABSORPTION
(weight approach)

	Source of Exposure		
	Home Dust	Street Dirt	Soil
Concentration of 2,3,7,8-TCDD	8.8×10^{-14} g/g	8.8×10^{-14} g/g	8.2×10^{-15} g/g
		Daily Intake (g/day)	
0.55 g of dust 1% Abs.	4.8×10^{-16}	4.8×10^{-16}	4.5×10^{-17}
0.55 g of dust 10% Abs	4.8×10^{-15}	4.8×10^{-15}	4.5×10^{-16}

TABLE 5-13

DAILY INTAKE FROM DERMAL ABSORPTION
(Surface Area Approach)

	Source of Exposure	
	Home Dust	Street Dirt*
Concentration of 2,3,7,8-TCDD	1.3×10^{-13} g/m^2	5.3×10^{-13} g/m^2
	Daily Intake (g/day)	
0.028 m^2 of surface area 1% Abs	3.6×10^{-17}	1.5×10^{-16}
0.028 m^2 of surface area 10% Abs	3.6×10^{-15}	1.5×10^{-15}
0.14 m^2 of surface area 1% Abs	1.8×10^{-16}	7.4×10^{-16}
0.14 m^2 of surface area 10% Abs	1.8×10^{-15}	7.4×10^{-15}

* PCDD concentrations in soils on a surface area basis are assumed to be identical with street dirt.

TABLE 5-14

CALCULATION OF A TOTAL DAILY INTAKE FOR INHALATION INGESTION AND DERMAL ABSORPTION PATHWAY

Case 1 - PCDDs and PCDFs Enter Baghouse in Gaseous Phase.

$$DI = DI_{inh} + DI_{ing} + DI_{derm}$$

$$DI = 1.9 \times 10^{-14} + 0 + 0$$

$$DI = 1.9 \times 10^{-14} \text{ g/day}$$

Case 2 - PCDDs and PCDFs Enter Baghouse Attached to Particulates

$$DI = DI_{inh} + DI_{ing} + DI_{derm}$$

$$DI_{min} = 8.8 \times 10^{-15} + 1.3 \times 10^{-15} + 3.6 \times 10^{-17}$$

$$DI_{max} = 8.8 \times 10^{-15} + 2.9 \times 10^{-14} + 7.4 \times 10^{-15}$$

$$DI_{min} = 1.0 \times 10^{-14} \text{ g/day}$$

$$DI_{max} = 4.5 \times 10^{-14} \text{ g/day}$$

1 and 2) described in Section 4. Note that in case 2, DI_{inh} equals 8.8 x 10^{-15} g/day, (0.000782 pg/m^3 [(Table 4-2)] x 0.75 x 15 m^3/day).

Based on this analysis we predict that the maximum daily intake of 2,3,7,8-TCDD due to inhalation, ingestion, and dermal absorption of predicted emission products from the BNYRRF ranges from less than 1.9 x 10^{-14} g/day to 4.5 x 10^{-14} g/day.

The sensitivity of the risk estimates derived for the inhalation pathway to the additional risks that might be attributable to the ingestion and dermal pathways was tested. These latter two pathways were not considered initally due to the high degree of uncertainty in the estimates of ingestion, absorption, and bioavailability rates, and due to the difficulties in modeling PCDD concentrations in soil, dirt, and dust. To compensate for these uncertainties and provide a safety factor, a high degree of conservatism was applied to the model, and a number of "worst-case" assumptions were used to identify an upper bound, maximum limit to risk.

The data indicates that the predicted additional 2,3,7,8-TCDD intake from ingestion or dermal absorption of particulate emissions from the BNYRRF is negligible assuming that the minimum estimates for DI_{ing} and DI_{derm} are more representative of actual exposure (DI_{min}). Even using worst-case assumptions regarding the maximum rates of exposure (DI_{max}) through ingestion and dermal absorption, the total daily intake of 2,3,7,8-TCDD would increase by 2.4 times the amount from inhalation alone. Under this "worst-case" scenario, ingestion becomes the major pathway of exposure.

The general conclusions regarding the level of risk posed by the BNYRRF are not significantly altered if the maximum total daily intake of 2,3,7,8-TCDD increases 2.4 times to 4.5 x 10^{-14} g/day. This total daily intake of 2,3,7,8-TCDD equals only 0.036% of the most conservative ADI (1.8 pg/kg-day). Further, this total daily intake of 2,3,7,8-TCDD equals a toxic equivalent daily intake of 2.7 x10^{-12} g/day (4.5 x 10^{-14} g/day x 59) which is only 2.1% of the most conservative ADI for a 70kg man.

The upper-bound carcinogenic risk estimates will also increase by a factor of 2.4 assuming the most conservative estimates for the ingestion and dermal absorption pathways. This would result in an upperbound increased cancer risk, for a population exposed to the maximum 2,3,7,8-TCDD and HCDD concentrations over a 70 year lifetime equal to less than 0.13×10^{-6}.

5.5.5 Additional Issues. It can be argued that the procedures used to predict the increased cancer risk associated only with 2,3,7,8-TCDD and HCDD exposure, underestimate the cancer risk of the complex mixture of PCDDs and PCDFs emitted from the BNYRRF. As stated previously, 2,3,7,8 TCDD represents only a small percentage of the total emissions projected for the BNYRRF.

It would be desirable to estimate the carcinogenic risk of this mixture for all other PCDD and PCDF isomers. However, dose/response data are lacking. Several regulatory agencies have used the concept of toxic equivalency to evaluate toxicities of complex mixtures and there is experimental evidence to support this approach in dealing with non-carcinogenic risk assessment procedures. However, there is no data regarding the applicability of this method to the assessment of the carcinogenicity of complex mixtures. In other words, it is not clearly established experimentally, that toxic equivalency correlates with carcinogenic equivalency.

Further, the regulatory agencies have taken conflicting positions regarding this issue. Neither EPA nor the CDC has tried to quantify the carcinogenicity risk of the complex mixture in any of their published risk assessments or publications on dioxins. However, EPA estimated increased cancer risk for 5 MWCs by making a conservative assumption that all TCDDs (Tetras) had the same carcinogenicity risk as 2,3,7,8-TCDD. Applying this assumption to the daily intake levels predicted downwind of the BNYRRF, we find that the maximum increased cancer risk for TCDD, for all three pathways would range to less than 1.3×10^{-6} depending upon the extrapolation model.

NYSDOH, in its risk assessment of the Binghamton office building fire, did use the TCDD toxic equivalent approach to estimate the increased cancer risk of the complex mixture of PCDDs and PCDFs present in soot. In this particular example, the actual standards and guidelines set by NYSDOH did not consider the cancer risk issue, but instead were developed using an ADI NOEL approach. Working backwards, they used these standards, to determine an acceptable lifetime maximum daily intake and extrapolated the increased cancer risk at these daily intake levels. Using the most conservative extrapolated cancer dose/response model, the guidelines established by NYSDOH could result in an increased cancer risk of less than 6×10^{-6} for 2,3,7,8 TCDD exposure. This assumes exposures to the ADI level for 250 days per year over 70 years.

NYSDOH also presented data that the TCDD toxic equivalent increased cancer risk could be less than 200×10^{-6}. This cancer risk data of 200×10^{-6} is presented with no further evaluation or analysis other than to state some of the conservative factors used to develop the risk assessment.

The Ontario Ministry of Labour suggests that 2,3,7, 8-TCDD acts as a promoter, rather than an initiator of carcinogenicity. As such, there may be threshold no-effect levels that would mitigate cancer risk at very low dose levels. The Ontario Ministry of Labor has stated that for 2,3,7, 8-TCDD, the No-Observed Effect Level ADI approach can be used to determine a very safe dose for cancer risk. As discussed previously, we predict the maximum TCDD toxic equivalent daily intake to be significantly below (0.13%) this very safe dose level.

Assuming for the purposes of this assessment, that toxic equivalency equals carcinogenic equivalency, the risk due to the carcinogenic potential of the complex mixture of PCDD and PCDF would equal 59 times the risk due to the 2,3,7,8-TCDD. As stated previously, there is a great deal of uncertainty regarding the most appropriate model or procedure to use in estimating human equivalent dose/response for 2,3,7,8-TCDD. Given this inherent uncertainty, multiplication of the most conservative 2,3,7,8-TCDD dose/response extrapolation (EPA) by 59 times may not be appropriate and may significantly overestimate risk. However, in accordance with procedures used in risk assessment, this worst-case scenario has been examined.

The increased cancer risk due to the predicted concentration of 2,3,7,8-TCDD in BNYRRF emissions, for all three pathways of exposure was estimated to range from .005 to 0.10 x 10^{-6} assuming a maximum 2,3,7,8-TCDD daily intake equal to 4.5 x 10^{-14} g/day. Using the toxic equivalency method the increased cancer risk due to the complex mixture of PCDDs and PCDFs present in the emissions ranges from 0.26 x 5.9 x10^{-6}.

5.6 Summary and Conclusions

A risk assessment was performed to estimate the risks associated with predicted rates of PCDD and PCDF emissions from the BNYRRF. The assessment compared the predicted ambient air concentrations and estimated daily intake levels for PCDDs and PCDFs with 1) applicable standards and criteria and 2) concentrations of PCDDs and PCDFs known or suspected to cause a toxic effect.

Several safety factors were incorporated into our assessment to ensure conservatism. They include the following:

- Assessment of three potential pathways of exposure: inhalation of gaseous or particulate emissions, and ingestion or dermal absorption of particulates deposited on outdoor and indoor surfaces.
- Application of a toxic equivalency multiplier equal to 59. This number provides an estimate of the noncarcinogenic toxicity of the complex mixture of PCDDs and PCDFs compared with the concentration of 2,3,7,8-TCDD. This equivalency factor was also used to estimate carcinogenic equivalency as a worst case assumption although such an application is speculative.
- No losses of PCDDs were assumed through volatilization or degradation or through such actions as rainfall.
- Indoor ambient air quality was assumed to equal outdoor air quality.

- Risks were calculated based on continuous exposure over a 70-year lifetime at the point of maximum impact.
- The most conservative cancer risk extrapolation model was included to estimate an upper-bound limit to increased cancer risk.
- Conservative assumptions for bioavailability, and rates of ingestions and dermal contact were included to estimate worst-case daily intakes of PCDDs.

The results of our risk analysis are summarized below. Average ambient air concentrations were predicted for ground-level and elevated receptors using the Case 1 scenario that all PCDDs and PCDFs are emitted in the gaseous phase. The maximum average annual ambient air concentrations are predicted to be well below existing standards and guidelines typically less than 1 percent. Only the NYSDEC performance guideline for evaluating combustion sources is approached, but at only 28.2% of the guideline.

Risks associated with inhalation of PCDDs and PCDFs at the maximum average annual concentrations were determined by comparing a predicted maximum daily intake through inhalation (DI_{inh}) with ADIs and cancer dose/response extrapolations.

The maximum daily intake DI_{inh} of 2,3,7,8-TCDD, TCDD, and TCDD toxic equivalents are predicted to be well below (less than 1%) any ADI promulgated by any regulatory agency. These ADIs provide a margin of safety and they identify a very safe dose, below which risks are insignificant for non-carcinogenic toxic effects.

An upper-bound to carcinogenicity risk was also determined by comparing DI_{inh} with three different cancer dose/response extrapolations. The upper-bound excess risk due to exposure to 2,3,7,8-TCDD and HCDD, at the point of maximum impact, ranges from less than 0.0019 to less than 0.055×10^{-6} or less than five cases per 100 million people exposed to the maximum concentration over a 70-year lifetime.

The sensitivity of the risk estimates derived for the inhalation pathway, to the additional risks that might be attributable to the ingestion and dermal pathways was tested. These two pathways were not considered in the initial risk assessment of the inhalation pathway (section 5.5.3) due to the high degree of uncertainty in the estimates of ingestion, absorption, and bioavailability rates and due to the difficulties in modeling PCDD concentrations in soil, dirt and dust. A range of daily intake estimates was calculated (DI_{ing} and DI_{derm}).

The data indicate that the predicted additional 2,3,7,8-TCDD intake from ingestion or dermal absorption of particulate emissions from the BNYRRF is negligible assuming that the minimum estimates for DI_{ing} and DI_{derm} are more representative of actual exposure. Even using worst-case assumptions regarding the maximum rates of exposure, the total daily intake of 2,3,7,8-TCDD would increase by 2.4 times the amount from inhalation alone. Under this "worst-case" scenario, ingestion becomes the major pathway of exposure.

The general conclusions regarding the level of risk posed by the BNYRRF are not significantly altered if the maximum total daily intake of 2,3,7,8-TCDD increases 2.4 fold. This additional daily intake of 2,3,7,8-TCDD equals only 0.036% of the most conservative ADI (1.8 pg/kg-day) and a toxic equivalent daily intake which is only 2.1% of this ADI.

The upper-bound carcinogenic risk estimates will also increase by a factor of 2.4 assuming the most conservative estimates for the ingestion and dermal absorption pathways. This would result in an upperbound increased cancer risk for a population exposed to the maximum 2,3,7,8-TCDD and HCDD concentrations over a 70-year lifetime of less than 0.13×10^{-6}.

As an additional safety factor to our assessment, we examined the risks due to PCDD exposure through all three pathways assuming that carcinogenic equivalency equals toxic equivalency. Using the toxic equivalency method, the maximum increased cancer risk due to the complex mixture of PCDDs and PCDFs present in the emissions ranges from less than 0.24 to an upperbound limit less than 5.9×10^{-6} for all these pathways combined, again assuming a 70-year lifetime exposure, 24 hours a day, to the maximum concentrations.

CHAPTER 6.0

COMPARATIVE RISKS

6.1 Introduction

In the previous section, the risks associated with predicted BNYRRF dioxin emissions were evaluated. These risks were judged to be low in relation to existing ambient air standards and guidelines and in relation to acceptable daily intake levels (ADIs). ADIs are developed as predicted very safe dose levels that should provide a margin of safety for risks due to non-carcinogenic toxic effects. These conclusions were judged to be valid for all three potential pathways of exposure to 2,3,7,8-TCDD, T_4CDD and TCDD toxic equivalents.

Judging the potential health significance of an excess cancer risk estimate predicted in a risk assessment is a much more difficult process. Due to the uncertainties involved in all phases of the process, there is no simple standardized format or methodology to evaluate significance. A given risk level for a project can be considered either acceptable or unacceptable, significant or insignificant depending upon such factors as:

- Whether the risks are voluntary or involuntary;
- Degrees of confidence (or uncertainty) in risk assessment assumptions;
- Comparisons with normal risks inherent in everyday activities;
- Public benefits derived from the project;

- Degree to which additional risk reduction can be effected through application of best available technology.

Ultimately, a determination of the acceptability of a given level of risk is a public policy decision in which the various costs and benefits are weighed.

To put the projected excess cancer risks for the BNYRRF in perspective, we will examine how these projected risks compare with:

- Risk evaluations for dioxin exposure performed by regulatory agencies;
- Current regulatory policy or practice regarding acceptable risk levels;
- Cancer rates for the general population;
- Normal risks inherent in everyday activities;
- Risks due to other common sources of TCDD.

6.2. Risk Evaluations for Dioxin Exposure Performed by Other Regulatory Agencies. Although there are no clear definitions of acceptable versus unacceptable levels for an increased risk of cancer, some guidance is available from other risk evaluations that have been performed for dioxin.

Harding, the author of the Ontario ambient air standard (1982), rejected the concept of applying a linear-non-threshold model for estimating cancer risks for TCDD. He concluded that "CDDs and CDFs exhibit the characteristics of non-genotoxic (i.e., does not alter genetic information) carcinogens and teratogens. As such, they would possess a threshold level of dosage........". He went on to conclude that the NOEL/ADI approach is an acceptable model for establishing standards where threshold effects exist. The Netherlands also have issued only an ADI based dioxin standard (Heigden, 1982). As described previously, the predicted maximum toxic equivalent daily intake as a result of potential BNYRRF emissions for the three exposure pathways combined is substantially less than any published ADI.

The USEPA estimated an upper bound increased risk of cancer due to inhalation of particulate emission from five municipal waste combustors (MWCs). The Agency used the maximum ground level concentration of TCDD derived from the PTMAX air dispersion model and assumed that all TCDDs are as toxic and carcinogenic as 2,3,7,8-TCDD. Using these assumptions, the estimated increased cancer risk ranged from 8 to 19 x 10^{-6} depending upon the dose/response extrapolation model that was used. Nonetheless, EPA concluded that, in the context of the worst-case assumptions used to calculate the increased risk, the risks to the public from the MWC emissions were minimal (USEPA, 1981). We predict an upper-bound to the increased cancer risk caused by predicted BNYRRF emissions of 2,3,7,8-TCDD or T_4CDD, assuming worst case conditions, for all three pathways (0.13 x 10^{-6}) to be almost an order of magnitude lower than the risk levels considered by EPA to have minimum impacts to public health. Even assuming, for the sake of risk assessment, that the carcinogenic risk of the complex mixture equals 59 times the risk due to 2,3,7,8,-TCDD alone, the levels are lower than in EPA's assessment.

A sixth MWC studied by EPA had higher emission levels than in any of the five MWCs previously studied. Nonetheless, EPA's position regarding the public health impacts associated with these emissions remains unchanged;

however, operational and design changes were ordered on this facility to lower the PCDD emissions (USEPA, 1983).

The NYSDOH, in a risk assessment to establish guidelines for reentry to the Binghamton Office building, chose to use an ADI approach (Kim et al., 1984). They selected an ADI of 2 pg/kg-day to set guidance levels. At the same time, they presented data showing that the ADI for 2,3,7,8-TCDD would result in an upper-bound estimate of a lifetime increased cancer risk ranging from .01 to 6×10^{-6}, depending upon the risk extrapolation model. These risk levels are higher than those predicted for the BNYRRF. As noted by Kim, all of these estimates correspond to the lower 95% confidence limit in dose, providing an element of conservatism in these estimates.

In our opinion, after applying worst-case assumptions to all pathways of exposure, the predicted increased cancer risks resulting from predicted BNYRRF emissions are below the limits found by these agencies to require additional review and probable action to reduce risk.

6.3 Current Regulatory Policy or Practice Regarding Acceptable Risk Levels. Regulatory agencies in the U.S. have not established a uniform cancer risk level to distinguish acceptable from unacceptable risks. Nevertheless, there is a range of levels that guide the agencies in decision making.

For example, the USEPA has established surface water quality criteria for priority pollutants, including 2,3,7,8,-TCDD. For suspected carcinogens in surface water, for which a zero concentration may not be attainable, criteria for the protection of human health are established, that would limit the increased cancer risk over a lifetime to less than 10^{-5} to 10^{-7}. EPA's position is that while zero concentration is desirable, a risk level no greater than 10^{-5} is acceptable (USEPA, 1984).

Several USEPA health advisories for drinking water result in risks such as 10^{-4} (benzene), 3×10^{-4} (chlordane), and 6×10^{-6} (tetrachloroethylene) (Dowd, 1984).

The FDA has established a 25 ppt advisory level for 2,3,7,8-TCDD contaminated Great Lakes fish. Using various assumptions regarding the average concentrations of TCDD at the market place and the amount of fish consumed per day, etc., the advisory translates to an upper-limit cancer risk of 3×10^{-6} (FDA) to 3×10^{-5} (USEPA, 1984).

As recently summarized by Dowd in a review of the USEPA's regulatory policy regarding risk, "if a quantitative risk assessment is carried out with identifiable assumptions and is reasonably consistent with established modeling procedures, one can make broad comparisons among risks. In EPA's regulatory actions, values less than 10^{-6} generally have not been singled out for regulatory attention. Risks between 10^{-5} and 10^{-6} are often carefully reviewed but not often controlled. Risks between 10^{-5} and a few times 10^{-4} are cases for careful review and probably action, and risks above a few times 10^{-4} to 10^{-3} are likely to be viewed as major risks which require regulatory action to reduce them" (Dowd, 1984).

It should be noted that some disagree with the USEPA and believe that the Agency has allowed too high an increased cancer risk in its standard-setting policy, particularly where large populations are likely to be exposed. For example, NYSDOH will be proposing new drinking water regulations that will use the 10^{-6} risk level as the basis for setting standards. (NYSDOH 1984). The issue of acceptable risk levels continues to be an area of considerable controversy.

6.4 Risks from Non-Dioxin-Related Events

Most human activities and events involve some degree of inevitable risk. In order to put the risks posed by the BNYRRF in a measurable perspective, it may be helpful to understand how they compare to other risks. From Table 6-1, it is apparent that the likelihood of developing cancer from BNYRRF emissions is far exceeded by risks posed by such common activities as walking into a busy street, climbing a ladder, or having surgery under general anesthesia. Although some of these risks may be voluntary, understanding the degree of risk found in daily life activities may be helpful in making judgments about the relative predicted risks of the BNYRRF.

6.5 Comparison with Overall Cancer Rates

Recent statistical information from the National Cancer Institute indicates that the current cancer incidence rate (a direct estimate of the probability, or risk, of developing the disease) is 1 in 4 for males and slightly higher for females over a lifetime. These figures translate into a current overall lifetime cancer incidence rate of 250,000 cases per

TABLE 6-1

ESTIMATED LIFETIME RISK OF DEATH FOR PERSONS IN NEW YORK STATE

By Selected Events*

1 in a Million or 10^{-6}	1 in One Hundred Thousand or 10^{-5}	1 in Ten Thousand or 10^{-4}
Diphtheria	Gas gangrene	Electrocution
Acute Polio	Hemophilia	Fall out of building
Rubella (German measles)	Pedestrian hit by bicycle	Hit by falling object
Melanoma	Anesthesia complication of surgery	Firearm accident
Vitamin D deficiency	Lightning	Excessive cold
Rickets	Cataclysm (hurricane, flood, tornado, earthquake, etc.)	Accidental poisoning with drug or medicine
Passenger on railroad hit by train	Bites and Stings (from venomous animals or insects)	Fall from ladder or scaffold
Passenger on a commercial air-craft		

* Estimate is based on the number of deaths in New York State recorded for each cause by the New York State Health Department, Office of Biostatistics, for the years 1974-1977. 1×10^{-6} risk represents events occurring from 0-5 times in that 4-year period; 1×10^{-5} risk represents events occurring from 6-50 times during the 4 years; and 1×10^{-4} risk represents events occurring 51-500 times during the 4 years. A four-year period for recording of events was selected because with the population of New York State (1977 estimate 17,924,000), just over 70 million person years of observation are accrued each 4 years; therefore, events occurring once every four years correlate with a risk of one in a million for a lifetime.

Source: Kim, N.K. and O. Stone (NYSDOH) Organic Chemicals and Drinking Water.

1,000,000 people. The New York State Department of Health lists cancer as the second highest cause of death in the state (1974-1977) and calculates the estimated lifetime risk of dying of cancer as 14 in 100 or 140,000 per 1,000,000. Even using levels derived from the conservative methods described in the last chapter, the potential risks posed by the BNYRRF constitute an insignificant incremental risk. Using the models described in Chapter 5, incremental cancer risks amount to less than 6 additional cases per 1,000,000 people, under all worst-case assumptions. This increased cancer rate projected for the BNYRRF is only 0.002% of the overall cancer incidence rate for a 70-year lifetime.

6.6 Other Sources of Dioxin

As analytical methods become more precise and minimum detection levels become lower, the ubiquitous nature of 2,3,7,8-TCDD is becoming more evident. It is also becoming obvious that this compound is present in a variety of common sources, many of which are totally unrelated to and maybe more significant than waste incineration.

Young, *et al*. (1983) describes an adipose tissue study undertaken by the Veterans Administration. The aim of the investigation was to determine if analysis of body fat could be used to determine earlier exposure to Agent Orange. Three groups of adult males were studied:

- 20 Vietnam veterans, 19 of who claimed health problems related to Agent Orange;
- 3 Air Force officers with known heavy and relatively recent exposure from herbicide disposal operations;

- 10 veterans with no service in Vietnam and no known exposure to herbicides.

The results, as related to levels of TCDD found, indicated that levels ranging from 3 to 99 ppt could be detected in human adipose tissue. These levels, however, did not correlate well with known exposure.

- Of the 20 Vietnam veterans:

  7 had no detectable levels of TCDD (level of detection = 2-6 ppt)

  2 had detectable material which could not be validated as TCDD

  1 measured value was only questionably above the detection limit

  5 had TCDD in amounts from 5-7 ppt

  3 had TCDD in amounts from 9-13 ppt

  1 had TCDD at 63 and 99 ppt

  1 had TCDD at 23 and 35 ppt

- Of the 10 control (unexposed) veterans, four had TCDD detected at 6, 7, 7, and 14 ppt. Of the remainder, two had values low enough to be considered equivocal, and in three others, the detected material was not validated as TCDD. One control veteran showed no detectable levels.

- Of the three Air Force officers with known heavy exposure, one had no identified TCDD. The material measured in all three officers was never more than 3 ppt above the level of detection.

The interesting aspect of the above study is that levels of TCDD were found in the body fat of individuals with no known exposure to herbicides (i.e., the control group). Rappe (1984) cites studies by Ryan and Williams (1983) which report on the levels of 2,3,7,8,-TCDD in 23 autopsy samples of human adipose tissue from the Great Lakes area in Canada. Twenty-two of the

23 samples contained 2,3,7,8,-TCDD at levels ranging from 4.1 to 130 ppt. The article goes on to state that additional preliminary data (Ryan, personal communication; Rappe and Nygren, personal communication) indicates background levels ranging from 1 to 600 ppt in the general population (Rappe, 1984).

A major source of exposure to PCDDs may be through dietary intake, primarily through fish. Several studies (Ryan _et al_., 1983; Cordle, 1981) indicate that a number of commercial and sport fish species contain 2,3,7,8-TCDD in levels ranging up to 38.5 ppt. Table 6-2 gives results of a study performed by Ryan _et al_.

Data from the New York State Department of Environmental Conservation revealed detectable levels of dioxin in all but one of 46 fish samples taken from Lake Ontario. Levels ranged from 2 to 162 ppt in small mouth bass; lake, rainbow, and brown trout; white sucker; brown bullhead; and coke and chinook salmon (NYSDEC, 1981). More recently, New York State DEC reported levels of up to 30 ppt TCDD and nearly twice that amount of TCDF in striped bass taken from the Hudson River. Their data is presented in Table 6-3 (NYSDEC, 1982).

2,3,7,8-TCDD has also been detected in other food sources. Health and Welfare Canada cites data which indicates that beef cattle, feeding on ranges sprayed with 2,4,5-T, can accumulate slightly more than 10 ppt in fat. Consumption of 250 grams of beef with 10 percent fat, with 10 ppt of 2,3,7,8-TCDD amounts to approximately 0.25 ng TCDD per meal or 0.004 ng/kg body weight for a 60 kg adult (Health and Welfare Canada, 1983). The livers

TABLE 6-2

2,3,7,8-TETRA-CDD LEVELS (PPT) IN 62 SAMPLES OF GREAT LAKES FISH FROM LAKE ONTARIO

Species	Number Analyzed	Number Positive for Tetra-CDD	Mean of Positives (ppt)	Range Positives (ppt)
Rock Bass	6	0		
Sunfish	9	0		
Black Crappie	5	0		
White Perch	3	1		6.3
Yellow Perch	10	2	3.8	3.2-4.3
Brown Bullhead	7	2	6.0	3.4-8.6
White Sucker	5	2	3.0	2.0-4.0
Catfish	3	3	15.5	12.8-17.7
Eel	6	5	19.8	6.4-38.5
Smelt	8	6	20.0	11.3-32.9

Source: Ryan, et al., 1983

TABLE 6-3

AVERAGE CONTAMINANT LEVELS IN STRIPED BASS--1982
(2,3,7,8-TCDD AND 2,3,7,8-TCDF)
UNITS ARE PARTS PER TRILLION (PPT)

Collection Location	2,3,7,8-TCDD, ppt	2,3,7,8-TCDF, ppt
Poughkeepsie	28 (11)*	NA
Poughkeepsie	ND (9)	NA
Poughkeepsie	28 (3.6	NA
Poughkeepsie	11 (2.8	NA
Poughkeepsie	28.5**	NA
Montrose Point	30.5**	54 (7.0)
Montrose Point	13 (3.2	54 (7.5)
Montrose Point	19.5**	NA
Montrose Point	7.5**	NA
Montrose Point	25 (15)	NA

NA - not analyzed
ND - not detected
* Values in parenthesis are detection limits
**Average of two samples

Source: New York State Department of Environmental Conservation, October 15, 1982.

of poultry raised on wood shavings containing pentachlorophenol show levels of H_6CDD up to 1.4 ppb. A person eating 250 grams of liver would have an intake of roughly 350 ng H_6CDD or 5.8 ng/kg b.w. for a 60 kg adult (Health and Welfare Canada, 1983).

Using this data, one can develop a risk assessment scenario similar to those generated in Chapter 5. Doing so helps to emphasize the conservative nature of the risk assessment process .

For example, we will utilize results of a New York State study in which approximately 25 percent of Lake Ontario fish sampled contained TCDD levels of 5 ppt. TCDD was not detected in the remaining 75 percent. Therefore, the average TCDD concentration for this fish population is 1.25 ppt (10^{-2} g). This is typically below detection limits. Let us assume, for the sake of this risk assessment, that the average concentration of 2,3,7,8-TCDD in fish equals only 0.5 ppt. We would not know if this were true or not since the concentration is below detection limits. Using the USEPA's estimate of 6.5 g/day for average daily fish consumption, this translates to 3.3 x 10^{-12} g/day of 2,3,7,8-TCDD. ([0.5 x 10^{-12}] x 6.5). Assuming 80 percent bioavailability, the consumption of 3.3 x 10^{-12} g/day of 2,3,7,8-TCDD corresponds to a predicted upper limit excess cancer risk of approximately 6 x 10^{-6}. If other PCDD and PCDF isomers are present, risks could be higher.

As shown above, using risk assessment, a worst-case argument could be made that New York State residents are potentially exposed to dietary levels of TCDD from fish in amounts equal to or greater than levels projected from the BNYRRF.

This argument serves to emphasize the point that worst-case assumptions do not necessarily provide a good indication of average, most probable, or most realistic conditions.

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APPENDIX A

Compilation of PCDF and PCDD Emission Data

APPENDIX A

COMPILATION OF PCDF AND PCDD EMISSION DATA FROM PUBLISHED LITERATURE (ng/Nm^3)

	Chicago, Northwest[(a)]	Zurich-Josephstrasse[(b)]	Eskjo, Sweden[(c)]	Como, Italy[(d)]
Tri-CDF	280	NR	NR	NR
Tetra-CDF	84	22.3	328	78
Penta-CDF	NR	27.3	54	83
Hexa-CDF	58	18.7	60	90
Hepta-CDF	7.0	12.4	28	99
Octa-CDF	0.6	8.2	12	63
Tri-CDD	12	NR	NR	NR
Tetra-CDD	5.9	4	ND-23	29
2,3,7,8 Tetra-CDD	0.38	0.16	ND-1.0	NR
Penta-CDD	NR	11	ND	46
Hexa-CDD	15	24.9	ND	76
Hepta-CDD	7.1	24.1	32	74
Octa-CDD	2.3	49.1	18	84
Sample Method				
condensibles	X	X	X	X
particulate	X	X	X	X
Combustion Temp. °C	650*	NR	700*	994*

NR - Not reported ND - Not detected (no detection limit reported)

* Location of temperature sensor was not described in the literature.

Ref: (a) Redford et al. 1981, units converted from ng/dscm (13.1% H_2O)
(b) Swiss EPA 1982 (c) Rappe et al. 1983 (d) Gizzi et al. 1982

APPENDIX A

COMPILATION OF PCDF AND PCDD EMISSION DATA FROM PUBLISHED LITERATURE (ng/Nm^3) (Continued)

	Sweden (e)	Sweden (e)	Sweden (e)	Hampton, Virginia (f)
Tri-CDF	NR	NR	NR	NR
Tetra-CDF	NR	NR	NR	2600
Penta-CDF	NR	NR	NR	1600
Hexa-CDF	NR	NR	NR	1800
Hepta-CDF	NR	NR	NR	2200
Octa-CDF	NR	NR	NR	170
Tri-CDD	NR	NR	NR	NR
Tetra-CDD	NR	NR	NR	380
2,3,7,8 Tetra-CDD	NR	NR	NR	NR
Penta-CDD	NR	NR	NR	530
Hexa-CDD	76	30	3	850
Hepta-CDD	603	23	10	2000
Octa-CDD	757	227	15	490
Sample Method				
condensibles	X	X	X	X
particulate	X	X	X	X
Combustion Temp. °C	400-600*	320-730*	680-1040*	550 (g)

NR - Not reported

* Location of temperature sensor was not described in the literature.

Ref: (e) Ahling and Lindskog 1982, units converted from ng/Nm^3, dry at 10% CO_2.

(f) Tiernan et al. 1983

(g) Average temperature; furnace front 677°-732°C, rear 400°C.

APPENDIX A

COMPILATION OF PCDF AND PCDD EMISSION DATA FROM PUBLISHED LITERATURE (ng/Nm^3) (Continued)

	Milan I Zema(h)	Milan II Figino(h)	Busto Arsisio(h)	Desio(h)
Tri-CDF	NR	NR	NR	NR
Tetra-CDF	NR	NR	NR	NR
Penta-CDF	NR	NR	NR	NR
Hexa-CDF	NR	NR	NR	NR
Hepta-CDF	NR	NR	NR	NR
Octa-CDF	584	91	45	67
Tri-CDD	NR	NR	NR	NR
Tetra-CDD	22	NR	1.4	1.0
2,3,7,8 Tetra-CDD	2.4	NR	NR	NR
Penta - CDD	NR	NR	NR	NR
Hexa-CDD	NR	NR	NR	NR
Hepta-CDD	NR	NR	NR	NR
Octa-CDD	805	113	33	75
Sample Method				
condensibles	X	X	X	X
particulate	X	X	X	X
Combustion Temp. °C	NR	NR	NR	NR

NR - Not reported ND - Not detected (no detection limit reported)

Ref: (h) Cavallaro et al. 1980

APPENDIX A

COMPILATION OF PCDF AND PCDD EMISSION DATA FROM PUBLISHED LITERATURE (ng/Nm^3) (Continued)

	Italy 1 (j)	Italy 2 (j)	Italy 3 (j)
Tri-CDF	NR	NR	NR
Tetra-CDF	ND	184	432
Penta-CDF	NR	NR	NR
Hexa-CDF	NR	NR	NR
Hepta-CDF	NR	NR	NR
Octa-CDF	62	7,273	1,010
Tri-CDD	NR	NR	NR
Tetra-CDD	21	189	19
2,3,7,8 Tetra-CDD	NR	NR	NR
Penta-CDD	31	279	40
Hexa-CDD	190	38,635	6,549
Hepta-CDD	161	1,403	124
Octa-CDD	72	8,491	778
Sample Method			
condensibles	X	X	X
particulate	X	X	X
Combustion Temp. °C	NR	NR	NR

NR - Not reported ND - Not detected (no detection limit reported)

Ref: (j) Cavallaro et al. 1982

APPENDIX A

COMPILATION OF PCDF AND PCDD EMISSION DATA FROM PUBLISHED LITERATURE (ng/Nm^3) (Continued)

	Italy 4 (j)	Italy 5 (j)	Italy 6 (j)
Tri-CDF	NR	NR	NR
Tetra-CDF	1,818	380	27
Penta-CDF	NR	NR	NR
Hexa-CDF	NR	NR	NR
Hepta-CDD	NR	NR	NR
Octa-CDD	1,760	92	24
Tri-CDD	NR	NR	NR
Tetra-CDD	71	10	19
2,3,7,8 Tetra-CDD	NR	NR	NR
Penta-CDD	36	23	11
Hexa-CDD	1,391	524	480
Hepta-CDD	170	56	6
Octa-CDD	2,742	417	72
Sample Method			
condensibles	X	X	X
particulate	X	X	X
Combustion Temp. °C	NR	NR	NR

NR - Not reported ND - Not detected (no detection limit reported)

Ref: (j) Cavallaro et al. 1982

APPENDIX A

COMPILATION OF PCDF AND PCDD EMISSION DATA FROM PUBLISHED LITERATURE (ng/Nm^3) (Continued)

	Zaanstad, Netherlands(k)
Tri-CDF	NR
Tetra-CDF	182
Penta-CDF	311
Hexa-CDF	566
Hepta-CDF	295
Octa-CDF	65
Tri-CDD	NR
Tetra-CDD	72
2,3,7,8 Tetra-CDD	NR
Penta-CDD	313
Hexa-CDD	375
Hepta-CDD	313
Octa-CDD	221
Sample Method	
gaseous	
particulate	X
Combustion Temp. °C	911*

NR - Not reported ND - Not detected (no detection limit reported)

* Location of temperature sensor was not described in the literature.

Ref: (k) Olie et al. 1982; average of tests where combustion temperatures were reported.

APPENDIX B

Example Calculations

APPENDIX B -- CALCULATIONS

BROOKLYN NAVY YARD AND RESOURCE RECOVERY FACLITY

PREDICTED PCDD AND PCDF EMISSIONS AND ASSOCIATED ENVIRONMENTAL IMPACTS

PCDD and PCDF Concentrations in Flue Gas

Concentrations in BNYRRF flue gas were based upon tests of Chicago Northwest and Zurich-Josefstrasse facilities. Corrections were made for flue gas conditions projected for BNYRFF. The concentrations presented here assume: (1) gas phase PCDD and PCDF emission, or (2) particulate emission with electrostatic precipitators used for particulate control. Calculations in the following sections account for particulate emission of PCDD and PCDF with fabric filter particulate control.

	BNYRRF	Chicago Northwest	Zurich-Josefstrasse
CO_2 % (dry)	10.5	9.5	10.9
H_2O %	13.63	13.1	14.7
Dry Gas Fraction	.8637	.869	.853
Standardized Temp.	0°C (N)	20°C (S)	0°C (N)

Chicago, N.W. data (CNW)

$$(\text{ng/Nm}^3)\ \text{BNY} = (\text{ng/dry Sm}^3)\ \text{CNW} \times (\%\ CO_2)\ \text{BNY}/(\%\ CO_2)\ \text{CNW} \times (\text{dry gas fraction})\ \text{BNY} \times (\text{abs. temp-S})/(\text{abs. temp-N})$$

Example, Tri-CDF

$$300\ \text{ng/dSm}^3 \times 10.5/9.5 \times .8637 \times 293/273$$

$$= 307.4\ \text{ng/Nm}^3$$

Zurich-Josefstrasse data (Z-J)

$$(\text{ng/Nm}^3)\ \text{BNY} = (\text{ng/Nm}^3)\ \text{Z-J} \times (\%\ \text{CO}_2)\ \text{BNY}/\ (\%\ \text{CO}_2)\text{Z-J}$$
$$\times\ (\text{dry gas fraction})\ \text{BNY}/(\text{dry gas fraction})\text{Z-J}$$

Example, Penta-CDF

$$27.3\ \text{ng/Nm}^3 \times 10.5/10.9 \times .8637/.853$$

$$= 26.6\ \text{ng/Nm}^3$$

PCDD and PCDF Mass Emission Rates

BNYRRF flue gas flow rate - 632,000 actual ft^3/min at 420°F (489°K)

actual ft^3/min x (abs. temp.-N)/(abs. temp.)BNY x m^3/ft^3 x min/sec

= Nm^3/sec

632,000 x 273/489 x 1/35.315 x 1/60 = 166.5 Nm^3/sec

Nm^3/sec x ng/Nm^3 x 10^{-3} ug/ng = ug/sec

Example, Tri-CDF

166.5 x 307.4 x 10^{-3} = 51.18 ug/sec

TABLE B-1

PREDICTED BNYRRF EMISSION RATES IF ELECTROSTATIC PRECIPITATORS WERE USED, OR IF ALL PCDD AND PCDF EMISSIONS WERE GASEOUS

	Reported Concentration	BNYRRF Concentration(3)	BNYRRF Mass Emission Rate (4)
Tri-CDF	300(1)	307.4	51.18
Tetra-CDF	90(1)	92.2	15.35
Penta-CDF	27.3(2)	26.6	4.43
Hexa-CDF	7.5(1)	7.7	1.28
Hepta-CDF	62(1)	63.5	10.58
Octa-CDF	0.60(1)	0.6	0.10
TOTAL-CDF	--	498.0	82.92
Tri-CDD	13(1)	13.3	2.22
Tetra-CDD	6.3(1)	6.5	1.07
Penta-CDD	11.0(2)	10.7	1.79
Hexa-CDD	7.6(I)	7.8	1.30
Hepta-CDD	16(1)	16.4	2.73
Octa-CDD	2.5(1)	2.6	0.43
TOTAL-CDD	--	57.3	9.54
2,3,7,8-TCDD	0.41	0.42	0.07

(1) Chicago Northwest, ng/dSm^3 at 20°C and 9.5% CO_2

(2) Zurich-Josefstrasse, ng/Nm^3 at 0°C, 10.9% CO_2 (dry) and 14.7% H_2O

(3) ng/Nm^3 at 0°C, 10.5% CO_2 (dry), and 13.63% H_2O

(4) ug/sec

Calculation of Particle Surface Area Distribution

These calculations assume electrostatic prepipitators are used for particulate control at the proposed BNYRRF. The following section provides corrections for fabric filter outlet emissions. Particle size distribution data is taken from actual tests at the Braintree Municipal Incinerator, assuming aerodynamic spherical particles.

Specific surface area of spherical particle with radius, r. $S = 4\pi r^2$

Volume of spherical particle with radius, r. $V = 4/3\ \pi\ r^3$.

Ratio of surface area to volume $S/V = 4\pi r^2/(4/3\pi r^3) = 3/r$.

Particle density is constant, and therefore the particle weight is proportional to volume. Consequently, the ratio of surface area to volume is proportional to the ratio of surface area to weight for a particle with a given radius. The ratio of surface area to volume (um^2/um^3) represents the relationship between surface area and weight ($\propto um^2/g$). Multiplying um^2/um^3 times the weight fraction of particles of a given size results in a number which represents the amount of surface area available on those particles. The fraction of total area on any size particle is this number divided by the sum of numbers for all particle sizes.

um^2/um^3 x fraction of total weight for given particle size = relative proportion of available particle surface area for given particle size, $\propto um^2/g$.

Relative proportion of available particle surface area for given particle size divided by the sum of relative proportion of available particle surface area for all particle sizes = fraction of total surface area for given particle size.

Example, 15.0 um particles, r = 7.5 um, S/A = 3/r = 3/7.5 = 0.400

S/A x fraction of total weight comprised of 15 um particles =
relative proportion of total surface area comprised of 15 um particles.

$0.400 \times .128 = 0.512\ (\propto \mathrm{um}^2/\mathrm{g})$

sum of relative proportions of all particle sizes is 3.4423.

0.512/3.4423 = fraction of total surface area comprised of 15 um particles = 0.0149 = 1.5%

TABLE B-2

PARTICLE CHARACTERISTICS IF ELECTROSTATIC PRECIPITATORS WERE USED

Particle Diameter (um)	Particle Radius (um)	S/A (um^2/um^3)	Fraction of Total Weight	Relative Proportion of Total Surface Area ($\propto$ um^2/g)	Fraction of Total Surface Area
15.0	7.5	0.400	0.128	0.0512	0.0149
12.5	6.25	0.480	0.105	0.0504	0.0146
8.1	4.05	0.741	0.104	0.0771	0.0224
5.5	2.75	1.091	0.073	0.0796	0.0231
3.6	1.8	1.667	0.103	0.1717	0.0499
2.0	1.0	3.000	0.105	0.3150	0.0915
1.1	0.55	5.455	0.082	0.4473	0.1290
0.7	0.4	7.500	0.076	0.5700	0.1656
LT 0.7	0.4	7.500	0.224	1.6800	0.4880
				3.4423	

LT - Less than

If an electrostatic precipitator would be used at the BNYRRF, the total particulate emission rate would be 7.94 g/sec. Average total PCDD concentration would be (9.54 ug/sec)/(7.94 g/sec) = 1.202 ug/g or 1,202 ng/g. Average total PCDF concentration would be (82.92 ug/sec)/(7.94 g/sec) = 10.443 ug/g or 10,443 ng/g. The concentrations of PCDD and PCDF as a function of particle size are calculated here, assuming that the concentrations are proportional to available particle surface area (Table B-2). This distribution will be used in the following section to calculate the effect on PCDD and PCDF emission rates of using a fabric filter.

(ug/sec) total PCDD or PCDF x fraction of total surface area for given particle size = (ug/sec) PCDD or PCDF for given particle size

(g/sec) total particulate x fraction of total weight for given particle size = (g/sec) particulate weight for given particle size

(ug/sec) PCDD or PCDF for given particle size divided by (g/sec) particulate weight for given particle size x 10^3 ng/ug = (ng/g) PCDD or PCDF for given particle size

Example, 15.0 um particles

9.54 ug/sec total PCDD x 0.015 = 0.1431 ug/sec PCDD on 15.0 um particles

82.92 ug/sec total PCDF x 0.015 = 1.2438 ug/sec PCDF on 15.0 um particles

7.94 g/sec x 0.128 = 1.0163 g/sec

(0.1431 ug/sec PCDD)/(1.0163 g/sec) x (10^3)
= 141 ng/g PCDD for 15.0 um particles

(1.2438 ug/sec PCDF)/(1.0163 g/sec) x (10^3)
= 1,224 ng/g PCDF for 15.0 um particles

TABLE B-3

CONCENTRATIONS OF PCDD AND PCDF AS A FUNCTION OF PARTICLE SIZE

Particle Diameter (um)	Fraction of Total Surface Area	Fraction of Total Weight	PCDD Concentration (ug/g)	PCDF Concentration (ug/g)
15.0	0.015	0.128	141	1,224
12.5	0.015	0.105	172	1,492
8.1	0.022	0.104	254	2,209
5.5	0.023	0.073	379	3,291
3.6	0.050	0.103	583	5,070
2.0	0.092	0.105	1,053	9,150
1.1	0.129	0.082	1,890	16,429
0.7	0.166	0.076	2,624	22,812
LT 0.7	0.488	0.224	2,618	22,751

LT - Less than

Effect of Fabric Filter on PCDD and PCDF and Emissions

The outlet particle size distribution for a fabric filter differs from that of an electrostatic precipitator described in the previous section. As supplied by the vendor, particle size distribution is shown.

TABLE B-4

PARTICLE SIZE DISTRIBUTION (FABRIC FILTER OUTLET)

Particle Diameter (um)	Percent Less Than by Weight
10	64
8	58
6	54
4	48
2	39
1	23
0.8	17
0.6	11
0.4	5.6
0.2	1.7
0.1	1.1

This particle size distribution was plotted on log-log graph paper and the distribution was graphically determined for particle size ranges used in the previous section.

TABLE B-5

PARTICLE SIZE DISTRIBUTION (FABRIC FILTER OUTLET)

Particle Diameter (um)	Fraction of Total Weight
15.0	0.24
12.5	0.11
8.1	0.07
5.5	0.05
3.6	0.07
2.0	0.07
1.1	0.14
0.7	0.10
LT 0.7	0.15

LT - Less than

Using total projected particulate emission rate for fabric filter outlet, fly ash emission rates for each particle size are calculated. The concentrations of PCDD and PCDF calculated in the previous section are then used to calculate PCDD and PCDF emission rates for each particle size.

(g/sec) total particulate x fraction of total weight for given particle size x (ng/g) PCDD or PCDF for given particle size = (ng/sec) PCDD or PCDF for given particle size

Example, 15.0 um particles

3.97 g/sec x 0.24 x 141 = 134 ng/sec PCDD on 15.0 um particles

3.97 g/sec x 0.24 x 1,224 = 1,166 ng/sec PCDF on 15.0 um particles

TABLE B-6

PCDD AND PCDF EMISSION RATES IF FABRIC FILTER IS USED AND ALL EMISSIONS ARE PARTICULATE

Particle Diameter (um)	Fraction of Total Weight	PCDD Concentration (ng/g)	PCDD Emission Rate (ug/sec)	PCDF Concentration (ng/g)	Emission Rate (ug/sec)
15.0	0.24	141	134	1,224	1,166
12.5	0.11	172	75	1,492	652
8.1	0.07	254	71	2,209	614
5.5	0.05	379	75	3,291	655
3.6	0.07	583	162	5,070	1,409
2.0	0.07	1,053	293	9,150	2,544
1.1	0.14	1,890	1,051	16,429	9,135
0.7	0.10	2,624	1,042	22,812	9,056
LT 0.7	0.15	2,618	1,560	22,751	13,560
			4,463		38,791

LT = Less Than

Distribution by weight of PCDD and PCDF among isomer groups with the same number of chlorine substitutions are assumed to be the same as shown in Table B-1.

TABLE B-7

PCDD AND PCDD EMISSION RATES BY ISOMER GROUP IF FABRIC FILTER IS USED AND ALL EMISSIONS ARE PARTICULATE

	Fraction of Total Weight	Mass Emission Rate (ng/sec)	Concentration on Fly Ash (ng/g)
Tri-CDF	0.6173	23,946	6,029
Tetra-CDF	0.1851	7,180	1,808
Penta-CDF	0.0534	2,071	521
Hexa-CDF	0.1275	4,946	1,245
Hepta-CDF	0.0155	610	151
Octa-CDF	0.0012	47	12
Total-CDF	1.0000	38,791	9,766
Tri-CDD	0.2321	1,036	261
Tetra-CDD	0.1135	507	127
Penta-CDD	0.1867	833	210
Hexa-CDD	0.2862	1,277	322
Hepta-CDD	0.1361	607	153
Octa-CDD	0.0454	203	51
Total-CDD	1.0000	4,463	1,124
2,3,7,8 TCDD	0.0073	0.0326	8

PCDD and PCDF Ambient Air Concentrations

Ambient Concentrations are calculated using the maximum normalized concentrations for ground-level and elevated receptors determined through the use of the MPTER dispersion model (0.024 ug/m^3 for a 1 g/sec emission rate).

$(ug/m^3)/(g/sec) \times g/sec = ug/m^3$

Example, Tri-CDF where emissions are assumed to be gaseous

$0.024 \times 51.18 \times 10^{-6}$ g/sec

$= \quad 1.2283 \times 10^{-6}\ ug/m^3 = 1.2283\ pg/m^3$

Example, Tri-CDF where emissions are assumed to be particulate

$0.024 \times 23.95 \times 10^{-6} = 0.5747 \times 10^{-6}\ ug/m^3 = 0.5747\ pg/m^3$

TABLE B-8

MAXIMUM AMBIENT PCDF AND PCDD CONCENTRATIONS

	Concentration, pg/m^3 (assuming emissions are gaseous) Case 1	Concentration, pg/m^3 (assuming emissions are particulate) Case 2
Tri-CDF	1.2283	0.5747
Tetra-CDF	0.3684	0.1723
Penta-CDF	0.1063	0.0497
Hexa-CDF	0.2539	0.1187
Hepta-CDF	0.0307	0.0144
Octa-CDF	0.0024	0.0011
Total-CDF	1.9900	0.9309
Tri-CDD	0.0533	0.0249
Tetra-CDD	0.0257	0.0012
Penta-CDD	0.0430	0.0120
Hexa-CDD	0.0655	0.0306
Hepta-CDD	0.0312	0.0146
Octa-CDD	0.0103	0.0049
Total-CDD	0.2290	0.0882
2,3,7,8 TCDD	0.00168	0.000782

Settling Velocities and Reflection Coefficients

Reflection coefficients reflect the amount of particulate that reflects from the surface, i.e., the amount that does not settle. Reflection coefficients are a function of settling velocity.

$$Vs = \frac{d^2 g\ (Pp - Pg)}{18\ u_g} \quad \text{Stokes settling velocity}$$

Vs - settling velocity (cm/sec)

d - particle diameter (cm)

g - Gravity acceleration (980.7 cm/sec^2)

Pp - Particle density (1 g/cm^3)

Pg - Air density (1.2×10^{-3} g/cm^3)

u_g - Air viscosity (1.83×10^{-4} g/cm-sec)

Below particle sizes of one um the settling velocities are adjusted for the Cunningham correction (slip flow).

$C = 1 + (6.21 \times 10^{-4})(T)/(d)$

C = Cunningham correction

T = Ambient temperature (285.8°K)

d = Particle diameter (um)

Example, 10 um particles

$$Vs = \frac{(10x10^{-4})^2\ (980.7)\ (1-1.20x10^{-3})}{18\ (1.83\ x\ 10^{-4})}$$

$$Vs \quad 0.3\ cm/sec = 0.003\ m/sec$$

Example, 0.8 um particles

$$Vs = \frac{(0.8x10^{-4})^2\ (980.7)\ (1-1.20x10^{-3})}{18\ (1.83x10^{-4})} x\ [1 + (6.21x10^{-4})\ (285.8)/0.8]$$

$$= \quad 0.0035\ cm/sec = \quad 0.000035\ m/sec.$$

Reflection coefficients are determined graphically using the curve supplied with the ISC model user's guide.

TABLE B-9

SETTLING VELOCITIES AND REFLECTION COEFFICIENTS

Particle Diameter (um)	Settling Velocity (m/sec)	Reflection Coefficient (dimensionless)
10	0.003	0.85
8	0.002	0.90
6	0.001	0.95
4	0.0005	0.95
2	0.0001	1.0
1	0.000035	1.0
0.8	0.00002	1.0
0.6	0.00001	1.0
0.4	0.000007	1.0
0.2	0.000002	1.0
0.1	0.0000008	1.0
LT 0.1*	0.0000003	1.0

LT - Less than

* Estimated at 0.05

Similarly, settling velocities and reflection coefficients are calculated for the particle sizes used in the particulate emission analysis.

TABLE B-10

SETTLING VELOCITIES

Particle Diameter (um)	Settling Velocity (m/sec)	Reflection Coefficient (dimensionless)
15.0	0.007	0.80
12.5	0.005	0.82
8.1	0.002	0.85
5.5	0.001	0.90
3.6	0.0004	0.95
2.0	0.0001	1.0
1.1	0.00004	1.0
0.7	0.00002	1.0
LT 0.7*	0.000004	1.0

LT - Less than

* Estimated at 0.35

Concentrations of PCDD and PCDF in Deposited Fly Ash

Concentrations of PCDD and PCDF in deposited fly ash are derived from the reflection coefficients in Table B-10 and the concentrations on fly ash as a function of particle size in Table B-3.

fraction of weight depositing for a given particle size = one minus reflection coefficient for a given particle size

Example, 15.0 um particles

1 - 0.80 = 0.20, fraction of all 15.0 um particles emitted that settle

(g/sec) total fly ash emitted x fraction of total weight emitted for a given particle size x fraction of weight depositing for a given particle size

= (g/sec) fly ash depositing for a given particle size

Example, 15.0 um particles

3.97 g/sec x .24 x .20 = 0.191 g/sec 15.0 um particles depositing

(g/sec) total deposited = sum of g/sec depositing for all particle sizes = 0.346 g/sec

fraction of deposited particles for a given size range = g/sec depositing for a given particle size divided by the sum of g/sec depositing for all particle sizes.

Example 15.0 um particles

(0.191 g/sec)/(0.346 g/sec) = 0.552, fraction of all deposited fly ash in 15.0 um size

TABLE B-11

FRACTION OF FLY ASH EMISSION THAT DEPOSITS

Particle Diameter (um)	Reflection Coefficient (dimensionless)	Fraction Depositing	Fraction of Fly Ash Emitted	Fly Ash Deposited (g/sec)	Fraction of Emission that Ultimately Deposits
15.0	0.80	0.20	0.24	0.191	0.552
12.5	0.82	0.18	0.11	0.079	0.228
8.1	0.85	0.15	0.07	0.042	0.121
5.5	0.90	0.10	0.05	0.020	0.058
3.6	0.95	0.05	0.07	0.014	0.041
2.0	1.0	0	0.07	0	0
1.1	1.0	0	0.14	0	0
0.7	1.0	0	0.10	0	0
LT 0.7	1.0	0	0.15	0	0
				0.346	

LT - Less than

fraction of deposited fly ash in a given particle size x (ng/g) PCDD or PCDF for a given particle size = contribution of PCDD or PCDF in a given particle size

sum of contributions of PCDD or PCDF in a given particle size = ng/g PCDD or PCDF in deposited mixture

Example, 15.0 um particles

0.552 x 141 ng/g PCDD = 77.8 ng/g PCDD from 15.0 um particles

0.552 x 1,224 ng/g PCDF = 675.7 ng/g PCDF from 15.0 u particles

sum of PCDD in all particle sizes = 193.6 ng/g

sum of PCDF in all particle sizes = 1682.0 ng/g

TABLE B-12

PCDF AND PCDD CONCENTRATIONS IN DEPOSITED FLY ASH

Particle Diameter (um)	Fraction of Deposited Fly Ash	PCDD Concentration (ng/g)	Contribution of PCDD in Deposited Fly Ash (ng/g)	PCDF Concentration (ng/g)	Contribution of PCDD in Deposited Fly Ash (ng/g)
15.0	0.552	141	77.8	1,224	675.7
12.5	0.228	172	39.2	1,492	340.2
8.1	0.121	254	30.7	2,209	267.3
5.5	0.058	379	22.0	3,291	190.9
3.6	0.041	583	23.9	5,070	207.9
2.0	0	1,053	0	9,150	0
1.1	0	1,890	0	16,429	0
0.7	0	2,624	0	22,812	0
LT 0.7	0	2,618	0	22,751	0
			193.6		1682.0

LT - Less than

PCDF and PCDF Deposition Rates

Mass deposition rates of PCDD and PCDF are the concentrations in the fly ash mixture times the maximum fly ash deposition rate. From the ISC deposition model the maximum fly ash deposition rate is 0.004613 g/m^2 per year.

194 ng/g PCDD x 0.004613 g/m^2 hr = 0.8949 ng/m^2 yr PCDD

1,682 ng/g PCDF x 0.004613 g/m^2 yr = 7.7591 ng/m^2 yr PCDF

Distribution by weight of PCDD and PCDF among isomer groups with same number of chlorine substitutions are assumed to be the same as shown in Table B-1.

TABLE B-13

PCDD PCDF DEPOSITION RATES

	Maximum Annual Deposition Rate (ng/m^2-yr)
Tri-CDF	4.790
Tetra-CDF	1.436
Penta-CDF	0.414
Hexa-CDF	0.990
Hepta-CDF	0.120
Octa-CDF	0.009
Total-CDF	7.759
Tri-CDD	0.208
Tetra-CDD	0.101
Penta-CDD	0.167
Hexa-CDD	0.256
Hepta-CDD	0.122
Octa-CDD	0.041
Total-CDD	0.895
2,3,7,8 TCDD	0.0065

PCDD and PCDF Concentrations in Soil

PCDD and PCDF depositing on soil are assumed to mix within the top centimeter of soil before or during exposure. Assuming 1.6 g/cm^3 for soil (100 lb/ft^3), concentrations are calculated using deposition rates in Table B-13.

(ng/m^2-yr) PCDD or PCDF/(1.6 g/cm^3)(10,000 cm^2/m^2)(1 cm) =
(ng/g) PCDD or PCDF in soil after one year

Example, Tri-CDF

$(4.790)/(1.6)(10,000)(1) = 0.299 \times 10^{-3}$ ng/g = 299 fg/g after one year

TABLE B-14

PCDD AND PCDF CONCENTRATIONS IN SOIL

	fg/g After One Year
Tri-CDF	299
Tetra-CDF	90
Penta-CDF	26
Hexa-CDF	62
Hepta-CDF	8
Octa-CDF	0.6
Total-CDF	486
Tri-CDD	13
Tetra-CDD	6
Penta-CDD	10
Hexa-CDD	16
Hepta-CDD	8
Octa-CDD	3
Total-CDD	56
2,3,7,8 Tetra-CDD	0.41

PCDD and PCDF Concentrations in Depositing Dirt

Fly ash particles that deposit on hard surfaces, such as streets, automobile surfaces, painted wood, etc. are assumed to be diluted only by the airborne particulate that deposits along with the fly ash particles. Average total particulate deposition rates for Brooklyn (74.4 g/m^2-yr) are used to calculate PCDD and PCDF concentrations in depositing dirt. Regardless of accumulation rates, the concentrations will remain the same.

(ng/m^2-yr) PCDD or PCDF/(g/m^2-yr) total particulate =
(ng/g) PCDD or PCDF in depositing dirt

Example, Tri-CDF
4,790/74.4 = 0.064 ng/g = 64 pg/g

TABLE B-15

PCDD AND PCDF CONCENTRATIONS IN DEPOSITING DIRT

	pg/g
Tri-CDF	64
Tetra-CDF	19
Penta-CDF	6
Hexa-CDF	13
Hepta-CDF	2
Octa-CDF	0.1
Total-CDF	104
Tri-CDD	3
Tetra-CDD	1
Penta-CDD	2
Hexa-CDD	3
Hepta-CDD	2
Octa-CDD	0.6
Total-CDD	12
2,3,7,8 TCDD	0.087

PCDD and PCDF Deposition on Indoor Surfaces

Assuming PCDD and PCDF deposition on indoor surfaces is proportional to outdoor deposition in the same ratio as ambient is the lead deposition, the overall indoor deposition rate is 25 percent of the overall outdoor deposition rate. The maximum accumulation time is assumed to be one month. The PCDD and PCDF accumulation is calculated using these assumptions.

(ng/m^2-yr) PCDD or PCDF x 0.25 x 1/12 yr/month x 1 month =
(ng/m^2) PCDD or PCDF maximum accumulation

Example, Tri-CDF

$4,790 \times 0.24 \times 1/12 \times 1 = 0.100\ ng/m^2 = 100\ pg/m^2$

TABLE B-16

MAXIMUM PCDD AND PCDF ACCUMULATION ON INDOOR SURFACES

	pg/m^2
Tri-CDF	100
Tetra-CDF	30
Penta-CDF	9
Hexa-CDF	21
Hepta-CDF	2.5
Octa-CDF	0.2
Total-CDF	163
Tri-CDD	4
Tetra-CDD	2
Penta-CDD	3.5
Hexa-CDD	5
Hepta-CDD	2.5
Octa-CDD	0.9
Total-CDD	18
2,3,7,8 TCDD	0.135

APPENDIX C

Issues Related to Dioxin Emissions from BNYRRF

APPENDIX C

ISSUES RELATED TO DIOXIN EMISSIONS FROM THE BROOKLYN NAVY YARD RESOURCE RECOVERY FACILITY

Introduction

This appendix discusses additional issues related to PCDF and PCDD emissions from the BNYRRF. Included is a discussion of additional methods that might be applicable to reduce PCDF and PCDD emissions and discussions of potential public health impacts associated with the fly ash residue produced during facility operations. Although these issues are not directly related to the emission assessment and risk analysis presented in previous chapters, they are important issues because they could ultimately affect plant design and operation and overall public exposure. Included will be a discussion of these related topics: (1) the segregation of polyvinyl chloride (PVC) from incoming solid waste, (2) operating controls, (3) emission controls, (4) residue in fly ash, (5) occupational exposures, and (6) disposal of fly ash. Since these topics are not directly involved in the risk analysis, they are not covered in as much detail as the information in Chapters 3, 4, and 5.

Potential Methods to Reduce PCDF and PCDD Emissions

Segregation of Polyvinyl Chloride

Pre-combustion separation is not considered a viable method to reduce PCDF and PCDD emissions, unless known precursors can be identified and removed with a degree of certainty (ASME 1981). PVC has never been shown to be a precursor of PCDF/PCDD, and the chlorine liberated by PVC combustion comprises only part of the total amount of chlorine in municipal solid waste. Therefore, at this time the removal of PVC from the incoming solid waste stream would not be expected to affect the PCDF and PCDD emissions from the stack.

Polyvinyl chloride (PVC) is a common plastic that is used extensively in construction materials in the United States. Uses include plastic pipe, indoor floor tile, wire insulation, and automobile interiors. PVC is a very durable material and is generally used in places where it will not be replaced frequently. Since PVC is primarily used for durable, and not consumable, products, it does not comprise a major portion of municipal solid waste. However, the fact that it is a commonly used material in the United States indicates that some of it will find its way into the municipal solid waste system. Studies on the amount of chlorine in municipal solid waste have shown that the total chlorine content is made up of contributions from textiles, rubber, leather, paper, and food, as well as plastics. The chlorine contribution from plastics has been found to be 35-50 percent of the total amount of chlorine. Therefore, removal of PVC will still leave a significant amount of chlorine in the waste, which would be available to form PCDF and PCDD compounds in the unlikely event of pyrolytic conditions in the municipal incinerator. Due to the many diverse sources of chlorine in waste, it is impractical to separate chlorine from the solid waste.

Prescreening of the waste to remove non-combustibles and plastics has been proposed at other facilities to enhance combustion and reduce PCDF and PCDD emissions further. Most plastics disposed in the U.S., however, are not chlorinated, but do have high heat contents; therefore, removal of the plastics may not enhance combustion or reduce PCDF and PCDD emissions. In addition, very great technical and safety problems would have to be overcome before this type of technology could be applied to the scale of the Brooklyn Navy Yard.

It has been reported that chlorine, whether organically bound or in the inorganic form, can react with phenol and creosol compounds that are formed when vegetable materials are pyrolyzed (Liberti et al. 1983). In these experiments pure vegetable extracts were pyrolyzed in the presence of organic and inorganic chlorine, yielding PCDFs and PCDDs in the ppm range. However, any source of chlorine, whether from PVC, other chlorocarbons, or inorganic chloride (salt) can transform products of incomplete combustion into PCDF and PCDD compounds. Therefore, in order to minimize PCDF and PCDD emissions, the most important step is the optimization of combustion efficiency rather than the removal of chlorine from the waste. It is clear from reports of tests performed on a full-size Martin incinerator that, even when PVC was added to municipal refuse in amounts of 300 percent greater than what was normally found in urban municipal waste, there were no increases above normal levels of PCDF and PCDD emissions on fly ash (Karasek et al. 1983).

There is also some concern over PVC due to the fact that it has been reported that pyrolysis of this material under laboratory conditions can form chlorobenzenes (Ahling and Lindskog 1982), and that chlorobenzenes can convert to PCDDs and PCDFs in the ppm range during pyrolysis in sealed quartz ampules (Choudhry et al. 1982). However, combustion of PVC in the presence of an oxygen-rich flame at high temperatures and adequate residence time results in carbon dioxide, water, chlorine, and hydrogen chloride. This is true of all chlorinated hydrocarbon materials.

Operating Controls

It is abundantly clear that the quality of operations of a municipal incinerator can significantly affect the quantity of PCDF and PCDD emissions. The design of the equipment selected by the NYCDOS appears to have features that enhance complete and efficient combustion. These features include underfire and overfire air supply, secondary air injection at high velocity to provide effective turbulence, and auxiliary burners to maintain minimum design secondary combustion temperature (980°C). According to the test data examined, the design appears to be consistent with relatively low PCDF and PCDD emissions. Obviously, the system would have to be operated and maintained in good condition in order for these emissions to be at this level continuously. A detailed operating plan is necessary for consistent high-quality operations.

Combustion monitoring instrumentation to provide data on day-to-day operations is planned. Combustion-temperature sensors will be located at strategic places in the system, and indicators of combustion efficiency will be monitored at all times. The indicators of combustion efficiency will be carbon dioxide or oxygen, and carbon monoxide. If carbon monoxide concentrations increase, then there are indications that PCDF and PCDD emissions will also increase. Decreasing oxygen concentrations are associated with starved-air conditions, which enhance PCDF and PCDD formation, while high oxygen concentrations indicate flame cooling and subsequent reduction of combustion efficiency, which is also likely to increase the PCDF and PCDD emissions. The goal is to operate with just enough oxygen to reduce carbon monoxide emissions without also reducing combustion temperature.

Even before start-up, the manner in which monitoring will be used to control operations should be carefully defined. The systems must be designed to sound an alarm when the indicators are out of the acceptable range. Even more important, when the alarm sounds the operators must be fully trained and prepared to respond to the problem.

Another potential problem is the maintenance of charging, combustion, and air-supply systems. It is imperative that preventive maintenance be performed regularly and whenever necessary. Deferred maintenance could result in frequent upset conditions.

Emission Controls

Emission controls can be separated into process controls and after-process collection/removal/destruction equipment. Process controls are inherent to the charging, combustion, and air supply systems. These controls are designed to optimize combustion efficiency and minimize emission of combustible materials, including PCDF and PCDD compounds. A modern, sophisticated combustion control system will be utilized at the Brooklyn Navy Yard Facility, including auxilliary burners to ensure the maintenance of minimum combustion temperatures, and continuous monitoring devices to permit combustion conditions to remain in specified ranges. Furthermore, the operators will be trained sufficiently in the use of the system so that combustion efficiency will be maximized and emissions will be minimized.

After-process control systems include particulate collection devices, which remove fly ash from the gas stream, resulting in low concentrations of suspended and settleable particulate matter. There is evidence that a large portion of PCDF and PCDD materials adsorb onto particulate matter while in the gas flues. There is a relationship between particle surface area and PCDF/PCDD concentration resulting from condensation on the particle surfaces. Small particles have a greater surface area to weight ratio; therefore, there is an inverse relationship between particle size and concentration by weight of PCDF/PCDD compounds on the particles. This results in higher concentrations on smaller particles. For this reason, a particulate control device which has a high collection efficiency for smaller particles will be more effective in controlling PCDF and PCDD emissions. Fabric filters are significantly more efficient in collecting smaller particles than electrostatic precipitators; therefore, fabric filters are a better choice for minimizing emissions than electrostatic precipators.

Since some PCDF and PCDD materials may be condensible when the flue gas enters the pollution control system, any temperature reduction within the pollution control system may cause condensation of these materials onto particle surfaces. The greatest portion of particle surface area is found in the ultra-fine particle size range. Therefore, a temperature reduction followed by collection of ultra-fine particles will result in the most efficient removal of PCDF and PCDD materials from the gas stream. Furthermore, a dry scrubbing system, operating at reduced temperatures and using a neutralizing agent, can absorb acid gases and enhance vapor condensation (Teller and Lauber 1983). This equipment, followed by a fabric filter particulate collector, can effect removal of HCl, SO_2, PCDD, PCDF, and ultra-fine particulates.

Teller and Lauber (1983) speculate that a reduction of temperature from 220°C to 120°C may reduce vapor-phase concentration of TCDD in incinerator emissions by 97-98 percent. Since the condensation will tend to occur mostly on the smallest particles, these researchers report that subsequent filtration devices, which are capable of 97-99 percent removal of particles to the 0.3 micron range, may effectively remove TCDD materials from the gas-stream. These data are based on the assumption that the equilibrium gas phase TCDD concentration is equivalent to the concentrations observed in six Italian incinerators (Cavallaro et al. 1983). This may not be an appropriate comparison to the BNYRRF, since there are no design and operations data for the Italian incinerators. Also, there is very little confidence in the test method used for quantifying the particulate and gaseous fractions. However, the Teller and Lauber analysis clearly shows that gas-temperature reduction, dry scrubbing, and fabric filtration may have a significant effect on PCDF and PCDD emissions. In fact, the California Air Resources Board has enacted regulations requiring acid gas control and fabric filtration on new municipal incinerators, and the New Jersey Department of Environmental Protection requires new municipal incinerators to have acid gas control as well as particulate emission control.

The type of particulate control selected for the BNYRRF is fabric filtration, which is a relatively new technology for incinerators. It can be designed to collect greater than 99.5 percent of the overall particulate matter, and is very efficient on the very small particles. Fabric filters have been installed in recent years on power plants, but only very recently have they been installed on municipal incinerators. The recent installations have primarily been overseas, in Europe and Japan. The alternate control technology is electrostatic precipitation, which has been used effectively on municipal incinerators for many years.

The advantages and disadvantages of electrostatic precipitators and fabric filters are presented in Table C-1 (Skizim 1982). Although fabric filters are very efficient on ultra-fine particles and are relatively insensitive to changes in inlet flow and dust loadings, they are expensive to operate, especially if used in conjunction with a dry scrubber, which would require the use of a specialty chemical. (These costs would also apply, however, to any scrubber used in connection with an electrostatic precipitator.) In addition, the fabric must be selected and handled properly. If conditions exceed the design temperature range, blinding or fabric degradation can occur. Electrostatic precipitators, although less efficient on ultra-fine particles, are reliable and inexpensive to operate and maintain. These units have been used successfully on municipal incinerators for many years, and they may also be used in conjunction with dry scrubbers for acid gas control.

The dry scrubber technology has been used with fabric filtration on municipal incinerators only very recently. Some PCDF/PCDD analyses have been performed on an installation in Japan; at this time, however, the data are not available. Therefore, the extent to which this technology will reduce emissions from those predicted in Section 3.6, if at all, is not known. Given the extremely low exposures and risks determined by this report, the recommendation for using an untested combination dry scrubber/filter fabric technology for further reductions is not warranted.

Potential Impacts of Fly Ash Residue

Residue in Fly Ash

Approximately 25 percent of the weight of solid waste input will be removed from the site as bottom ash and fly ash residue. This material will be quenched with water immediately upon removal from the incinerator so as to facilitate handling and to reduce fugitive emissions. Most of the residue will be in the form of bottom ash, and approximately 12 percent will be fly ash from the particulate collection devices. The test data indicate that negligible concentrations of PCDF and PCDD materials are found in bottom ash of municipal incinerators, while concentrations on fly ash range from negligible to greater than several thousand ng/g. A compilation of concentrations of PCDF and PCDD materials on fly ash collected in electrostatic precipitators of municipal incinerators is shown in Table C-2.

The low data-set from the Lustenhouwer data compares with the Martin plant data (Karasek et al. 1983). The representative analyses of 25 plants (Lustenhouwer et al. 1980) shows medium concentrations from 18 ng/g (octa-CDF) to 361 ng/g (hexa-CDF), while the average of nine Dutch incinerators (Olie et al. 1982) is also within this order of magnitude. The low data set from the Lustenhouwer et al. (1980) reference compares well with the Martin plant (Karasek et al. 1983). This ranges from 5 ng/g for tetra-CDD to 266 ng/g for octa-CDD. The Chicago, Northwest incinerator test data (Redford at al. 1980), shows that PCDF and PCDD compounds were not detected at a detection limit of 0.5 ng/g. Approximately 93 tons of fly ash per day would be generated by the Brooklyn Navy Yard facility at full capacity,

TABLE C-1

COMPARISON OF ELECTROSTATIC PRECIPITATORS AND FABRIC FILTERS

	Electrostatic Precipitators	Fabric Filters
Advantages:	High overall efficiency High turn-down ratio Low pressure drop High reliability Low maintenance Extensive operating experience	High efficiency in sub-micron particle size range Insensitive to fluctuations in inlet flow and particulate loading Compatible with dry scrubbing technology (acid gas control without wet scrubber problems)
Disadvantages:	Sensitivity to changes in dust and gas loads and characteristics Loss of efficiency in the sub-micron range	If operating with a dry scrubber, reduced gas temperature may restrict plume rise and pollutant dispersion * High operating costs Limited operating experience

* This would also be true of the case where an electrostatic precipitator is used with a dry scrubber, although it is more common to use dry scrubbers with fabric filters. Furthermore, as in the case with the BNYRRF, the fabric filter can be operated without a dry scrubber with no reduction in temperature from the case where an electrostatic precipitator is used.

Ref: (Skizim 1982)

based upon the difference between the controlled and uncontrolled emission rates cited in the PDEIS. For use in this analysis, the low concentrations of analyses representing 25 plants (Lustenhouwer et al. 1980) is used to calculate the annual PCDF and PCDD mass rates in collected fly ash; these rates are also shown in Table C-2.

Occupational Exposures

The degree to which workers at the BNYRRF are exposed to levels of PCDDs and PCDFs in the flyash will depend on several factors:

- the concentration of these materials in the fly ash
- the manner in which fugitive dust emissions are controlled, and
- the degree of respiratory and dermal protection provided.

Based upon an examination of available data, we estimated that the TCDD concentration of the fly ash would be as high as those found by Lustenhouwer et al. (1980) in the range for incinerators (55 ng/g-TCDD). This, in turn, would equal 0.3 ng/g of 2,3,7,8-TCDD (Assumes 2,3,7,8-TCDD is 6 percent of TCDD).

A concentration of 0.3 ng/g (ppb) of 2,3,7,8-TCDD is slightly lower than the 1 ppb concentration used by CDC as a guideline for determining the need to remove dioxin contaminanted soils from residential areas. While dioxin binds more tenaciously to fly ash than soil, suggesting that it may be less bioavailable, there may or may not be a need to limit occupational exposure to fly ash dust emissions.

As indicated in Chapter 3, levels of PCDDs and PCDFs in flyash vary considerably. During the startup phase of the BNYRRF, it is recommended that fly ash samples be analyzed to determine actual levels of these compounds. This information should then be utilized to develop a safety plan that identifies the need for and type of respiratory and/or dermal protection, and appropriate procedures for dust suppression and handling of fly ash material. The occupational and safety risks, if any, should be controlled through sound management procedures.

TABLE C-2

RESIDUE IN FLY ASH

	Concentration in Fly Ash[b] (ng/g)	Concentration in Fly Ash[a] (ng/g)			Concentration in Fly Ash[c] (ng/g)	Annual BNY Projected Mass Rate (kg/yr)
		Low	Med.	High		
Tri-CDF	NA	NA	NA	NA	--	--
Tetra-CDF	170	13	111	233	--	0.4
Penta-CDF	NA	42	196	510	--	1.3
Hexa-CDF	315	109	361	870	--	4.1
Hepta-CDF	NA	89	177	407	--	3.4
Octa-CDF	48	20	18	26	--	0.8
Tri-CDD	NA	NA	NA	NA	--	--
Tetra-CDD	126	5	54	110	ND	0.2
Penta-CDD	NA	31	182	488	8	1.2
Hexa-CDD	443	80	326	1200	28	3.0
Hepta-CDD	NA	190	288	902	75	7.2
Octa-CDD	389	266	106	110	180	10.1

LT - Less than

NA - Not analyzed

(a) Lustenhouwer et al. 1980; representing 80 analyses at 25 plants.

(b) Olie et al 1982; average of nine Dutch incinerators.

(c) Karasek et al. 1983; average of three analyses at a French Martin plant.

Disposal of Fly Ash

Landfill disposal of the BNYRRF fly ash is not anticipated to present a problem from an environmental standpoint assuming adequate cover, proper operating controls (particularly dust control), and effective occupational safety measures for landfill workers. These measures, combined with PCDF's and PCDD's tendencies to bind to fly ash, should ameliorate any adverse impacts to landfill personnel, air, ground and surface waters. As reported in Esposito, (1980) TCDD has never been detected in groundwater. Further, since NYC residents obtain drinking water from upstate reservoirs, there would be no pathway of exposure via groundwater migration. Due to the tenacious binding of PCDD to fly ash, as well as the relative insolubility of PCDD, migration to surface water would be unlikely to occur.

Summary

In evaluating the impacts and risks of PCDF and PCDD emissions from the BNYRRF, it was necessary to evaluate whether any options were available to reduce atmospheric emissions further than those projected. In addition, it was necessary to evaluate the design and identify possible problems and risks that are related to the PCDF and PCDD emissions.

The design of the BNYRRF is state-of-the-art with additional controls that are not used in other resource recovery facilities in the U.S. The use of auxiliary burners on a resource recovery plant to maintain secondary combustion temperature is an application of an existing tested technology in a new way to assure minimum emissions. The use of a fabric filter to remove fly ash from the flue gas stream is a relatively new technology for resource recovery in the U.S., although these have been installed recently in other countries. Given that these units have only recently been installed on resource recovery plants, performance will have to be monitored closely in order to assure that emissions are as low as projected, and that reliability is of a high degree.

After careful consideration of alternate designs, the only method that may achieve even lower emissions than those projected is the application of the dry scrubber/fabric filter combination for air pollution control. This technology, although available, has not been widely used or tested. However, claims have been made for significant PCDF and PCDD collection through gas quenching, pollutant condensation, and subsequent collection of solid particulates. Until this technology can be demonstrated to be effective without creating significant problems, such as moisture condensation in the fabric filter and reduced atmospheric dispersion through inhibited plume buoyancy of a cooler gas, it is not recommended to install this technology at this time. However, studies of this technology are ongoing and the reliability and performance may be shown to be effective in the future.

Occupational exposure to fly ash may have to be controlled through sound management practices and through implementation of a safety plan. The specific safety requirements should be determined after fly ash samples from the BNYRRF are analyzed.

Recommendations

The previous chapters provide an analysis of impacts from predicted BNYRRF emissions. Because of public concern regarding potential risks, actual rather than predicted impacts should be assessed through a sampling program.

In order to avoid future controversy, the feasibility and need for completing a background testing program of soils, sediments and dust samples collected prior to the startup of the BNYRRF, should be determined. Since there may be multiple (non-resource recovery facility) sources of dioxin emissions in the urban environment, background studies may be necessary to correlate future impacts after startup on the facility. Background data will also help determine the statistical significance of any sampling data collected after startup. It should be noted that much more information concerning background levels of dioxin should be available as a result of USEPS's Dioxin Strategy and other research programs.

Upon startup and reaching the steady-state charging capacity, it is recommended that stack emission tests for each group of PCDF and PCDD isomers be performed. Three test runs at each of three operating conditions, such as maximum, minimum, and an intermediate load, should be performed to obtain an emission profile on at least one unit. The other units can be tested at only the condition which results in the highest emissions. Unless specific emission problems are observed, these tests should be followed up after one and three years of operation to ensure that equipment and/or operating problems are identified if they occur. These tests should be performed on each unit at the condition initially identified with the highest emissions.

Additional monitoring should be performed of on-site meteorological conditions so that updated dispersion and deposition analyses can be performed. If ambient air and/or soil sampling is performed, the meteorological monitoring is absolutely necessary to correlate sampling data with source data. However, ambient sampling is not recommended at this time due to the difficulty of accurately making this correlation, plus the short sampling period, the expense of analysis, and the difficulty of excluding interference from other sources, such as apartment house incinerators.

Furthermore, it is recommended to analyze fabric filter collection dust for 2,3,7,8 TCDD. If the concentration exceeds the CDC guidance level of one ng/g, which was developed for action in assessing ambient soil concentrations, then a health and safety plan for worker protection should be developed. This analysis should be performed as soon after startup as possible and quarterly thereafter. Should the dust analysis reveal levels at or above the 1 ng/g level, occupational health and safety program should incorporate both dermal and respiratory protection as well as medical monitoring, if indicated. Emphasis should also be placed on dust suppression measures.

APPENDIX D

Comments of Peer Review Panel Members on this Report

APPENDIX D

Overall, the panel, with the possible exception of Dr. Goldfarb, generally supported the methodology, approach, and conclusions of this document. Based upon the expert panel's comments on the Draft Report, several minor editorial and technical changes and recommendations were incorporated into the Final Report. However, several substantative issues and areas of disagreement, which could not be addressed adequately in the final document were identified by the various panelists. Our response to these issues is provided below.

Drs. Chalmers, Goldfarb and Harbison suggested that the report should address the issue of the potential risks from the NYCDOS's long-term plan to construct eight resource recovery facilities in the city. We agree that the incremental risks from the multiple facilities should be evaluated. Our risk assessment procedures can be scaled up and directly applied to estimate the level of risk for the multiple facilities.

Drs. Thibodeaux and Goldfarb both brought up the issue that PCDD-containing fly ash deposition rates might be greater than estimated using the ISC model, due to terrain effects.

With the approach used to estimate PCDD concentrations in dust and dirt, localized changes in deposition rates due to terrain effects should have little impact on overall PCDD exposure through ingestion or dermal pathways. In our analysis, concentrations of PCDD in dust and dirt were determined by dividing the PCDD deposition rate by the deposition rate of total particulates found in the ambient air over Brooklyn. Therefore, if the deposition rate of PCDD increases or decreases due to terrain effects, there should also be a proportional increase or decrease in the total particulate deposition rate, causing relatively constant concentrations of PCDD in deposited particulates.

Another related comment by Dr. Goldfarb indicated that particle agglomeration and particle growth could significantly affect deposition rates. While we agree that the potential exists for particle agglomeration and growth, we have not found any data that suggests how much, if at all, these phenomena may occur on a resource recovery plant. Therefore, since a model for these effects is not available, we do not see any reason to change from the USEPA-approved model utilized in our analysis.

Mr. Velzy suggests that perhaps PCDD/PCDF emissions are not preferentially adsorbed onto small particles. This view is not generally held by the researchers whose papers and articles have been reviewed. Only one additional specific set of data was mentioned by Mr. Velzy in his letter. Changes have been made in the final report which address this additional data; however, the conclusion of the report has not been changed. That is, we feel that the PCDF/PCDD emissions are preferentially adsorbed onto the smaller particles. The data mentioned by Mr. Velzy are from the Hempstead refuse-derived-fuel (RDF) plant, which has been shut down in recent years because or operational difficulties. We do not believe that emission data from this facility is comparable to the efficient mass-burn plants described in the literature and currently operating successfully without emission problems. In summary, we feel that the data adequately supports the assumption that PCDD/PCDF emissions are concentrated on the small particles. The report discusses the reasoning behind this assumption.

Mr. Velzy states that, since PCDDs and PCDFs may not be preferentially adsorbed onto small particles, a fabric filter may not have a significant advantage over a high efficiency electrostatic precipitator. Fabric filters are much more efficient at removing very fine particles than electrostatic precipitators, and therefore, they would have a significant advantage at removing PCDDs and PCDFs, if these trace organics were associated with the very fine particles. As described above, the available data support the view that PCDD and PCDF emissions are in fact adsorbed in higher concentrations on the smaller particles. However, in our report we addressed two emission scenarios. The first case was the situation where the PCDDs and PCDFs were in gaseous form, in which case neither type of particulate control device would have an advantage. The second scenario was the situation where all the PCDDs and PCDFs were preferentially adsorbed onto the small particles. This provides a range of effects which cover the uncertainties over the amount adsorbed on particulate. We feel that this assessment covers the range of possibilities from no advantage of the control equipment to a very reasonable advantage based upon careful examinations of data published in the literature.

In summary, although we cannot definitively conclude that a fabric filter will have an advantage over an electrostatic precipitator (since the PCDDs and PCDFs may be in gaseous form), we believe that the higher collection efficiency of the fabric filter will cause a beneficial effect if the PCDDs and PCDFs are adsorbed onto particulates.

Mr. Velzy comments that particle size data from the Braintree Municipal Incinerator may not be suitable for use in this analysis because the unit is less efficient at collecting particles than a unit designed today. However, the only use for the Braintree data in our report is to provide a distribution of particle size in order to determine the concentration of PCDDs and PCDFs as a function of particle sizes emitted from a fabric filter . While we agree that a modern electrostatic precipitator would shift the average emitted particle size to one that is lower than used in the report, a significant portion of these same smaller particles would be trapped in a fabric filter. The smaller particles, which carry a relatively high proportion of the adsorbed PCDDs and PCDFs, would be collected at a higher rate than that estimated in the report. Using the Braintree data to develop the case of the increase in effective particle collection of a fabric filter over an electrostatic precipitator actually results in a higher PCDF/PCDD emission rate than would the use of a particle size distribution from a modern electrostatic precipitator. Therefore, from this aspect our data is conservative. Changes have been made in the report that explain and support the use of the Braintree data for this purpose.

Both Drs. Goldfarb and Hutzinger addressed comments on the removal of polyvinyl chloride (PVC) from the waste prior to combustion. The comments generally suggest that the removal of chlorine (specifically chlorine present in PVC) will reduce chlorine available to combine with other combustion products, thus reducing PCDD and PCDF emissions. Dr. Hutzinger, however, admitted that the removal of PVC from the waste stream is not easily accomplished in a conventional incinerator. In fact, there are no studies where PVC has been successfully removed from the waste stream of a conventional incinerator in order to test the effects on PCDD/PCDF emissions. The Karasek data cited in our report shows no increase in PCDD emissions when 300 percent more than normal PVC was added to the waste of a French incinerator. Dr. Goldfarb contends that excess chlorine was available from the already high concentration of PVC commonly found in French solid waste, and therefore the added PVC did not make any difference. However, the point we are trying to emphasize is that more PVC does not necessarily make more PCDD, unless other variables (such as poor combustion) predominate. Therefore, while removal of PVC may limit the maximum PCDD emissions under abnormally severe upset conditions, it will not affect emissions under normal day-to-day operations.

It is true that the removal of PVC from the waste stream would reduce emissions of acid gases. However, as of this writing, there are no data that indicate that PVC removal would affect PCDD/PCDF emissions. The California Air Resources Board (CARB), in their <u>draft</u> report on air pollution from resource recovery facilities, recommended that plastics removal be instituted to reduce acid gas and trace chlorinated organic emissions. However, CARB stated in a subsequent version of the report that a clear relationship between chlorine in solid waste and emissions of chlorinated organic materials does not exist and that reductions in chlorinated organic emissions should be primarily affected by good combustion practices. Therefore, given the huge problems associated with attempting to remove PVC from a waste stream of the magnitude of the BNYRRF and the lack of definitive data on the effects of removal on emissions, we still feel that PVC removal is not warranted.

Dr. Hutzinger stated that only measurements of PCDDs and PCDFs in the emissions would satisfactorily determine the effect of combustion conditions on emissions of these contaminants. While we agree on this issue, and have recommended periodic emission testing to assess emission rates, we feel that the day-to-day monitoring and control of combustion parameters (including carbon monoxide) together with a detailed operating plan and effective operator training, will raise the quality of operations and minimize emissions.

Dr. Goldfarb is critical of the many references to the conservatism of the risk assessment and cites examples where he feels it is inappropriate to use such terminology. We strongly disagree with Dr. Goldfarb on this issue. To ensure a margin of safety in our assessment, we have gone far beyond the traditional approach to risk assessment used by regulatory agencies for evaluating point source emissions. The majority of the panel members concurred that the assumptions utilized were highly conservative in nature. Furthermore, they agreed with the technical approach and methodology used in the risk assessment. Within the content of the standard operating practice for risk assessment our assumptions or range of estimates, except in two instances, include conservative rather than average or most probable case assumptions. These include an assessment of all three pathways of exposure rather than just the inhalation pathway, a multiplicative factor to estimate the carcinogenicity of the complex mixture of PCDD/PCDFs (twice as great as that used by Commoner _et_ _al_.), conservative estimates for ingestion rates, dermal exposure and bioavailability, no losses due to volatilization or photo-degradation. In these instances conservative assumptions were used because data regarding the most probable assumptions were lacking.

There are two instances where the most conservative estimates were not used. In the first instance data were available to estimate a most probable case assumption. In this example, Dr. Goldfarb mentioned that the use of PCDD and PCDF emission data from one incinerator, supplemented by data from one other incinerator, was not a sufficient basis for a conservative exposure assessment. Actually, the emission data from a large number of incinerators was examined. Unfortunately, most data was lacking in: (a) appropriate testing methodology, (b) description of combustion conditions and/or incinerator, or (c) similarity of design and/or operation. The data selected was the most appropriate from all aspects. Although we certainly would rather have more data points from which to make a prediction, we feel that the data selected is the closest representation of the BYNRRF available. We also feel that the design of the facility will provide for at least as effective control of PCDD and PCDF emissions as predicted by this assessment report.

In the second instance, we used what we believe to be the most conservative assumption regarding the carcinogenic risk of 2,3,7,8-TCDD. We also used a conservative assumption that the complex mixture of PCDDs/PCDFs was 59 times as carcinogenic as 2,3,7,8-TCDD despite the fact that this assumption is highly speculative. However, Dr. Goldfarb suggests that the risk estimate used by Dr. Commoner et al., is even more conservative based upon the alleged promoter effects of TCDD. The validity of using Dr. Commoner's approach to estimating carcinogenic risk is an issue that will not be resolved in this report. Dr. Commoner's approach, which should be analyzed critically through peer review, is currently not an accepted method used by any regulatory authority in determining excess carcinogenic risk. Further, Dr. Commoner's approach ignores the issue of whether there are any threshold effects for promoters. Drs. Harbison, Heath, Hutzinger and Upton, all of whom also commented on the risk assessment procedure, supported the risk assessment methodology used in the report.

In the absence of supporting data to show that trace concentrations of promoters in the environment increase overall cancer incidence rates at the same rate as in laboratory studies, and prior to peer review, Dr. Commoner's approach must be regarded as speculative, outside of accepted practice, and therefore inappropriate for use in our risk assessment.

Dr. Goldfarb also stated that he felt the BNYRRF design was deficient in that it does not include a dry scrubber for acid gas and PCDF/PCDD emission control. This is the single method not included in the BNYRRF design that may reduce PCDD/PCDF emissions even more than those currently predicted. Nonetheless, we do not feel that any change in the report regarding the effectiveness of dry scrubbers is warranted. Our report does state that dry scrubbing may reduce PCDD/PCDF emissions; however, the technology described in the literature is expensive, and as of this writing, there are no test results available that describe the effectiveness of this technology for PCDD/PCDF removal. As Dr. Goldfarb states, however, test results should be available soon. It must be stressed that the predicted BNYRRF emissions and risks are already quite low with the current design, and any decrease in emissions and risks must be compared to the cost of the additional control. Obviously, if a significant risk was associated with the design without dry scrubbers, and dry scrubbers could significantly reduce those risks, then adding this equipment would be essential. Given the expected emissions, we recommend that developments in dry scrubber technology be monitored, but that adding this technology at this time is not warranted on the basis of available information.

Drs. Chalmers and Heath have raised the issue of the lack of long-term health data indicating adverse effects of TCDD exposure. Dr. Chalmers correctly points out that recent information on follow-up of factory workers exposed to this material, and data from Love Canal residents does not indicate the presence of adverse teratogenic and carcinogenic effects. Dr. Heath also indicates that data relating exposure to phenoxy herbicides to the development of soft tissue sarcomas, while suggestive of a link, are not conclusive. While we were aware of the Love Canal data, we chose not to cite it in the document. The large number of compounds present at Love Canal, and the lack of information relating to route and level of exposure, make it difficult to interpret this data as it relates to dioxin risks. As regards the soft tissue sarcoma data, we would agree with Dr. Heath's contention that they are mainly suggestive, as is much of the data regarding human health effects of TCDD. Following the conservative approach generally used in risk assessment, however, we have chosen to presume a possible adverse effect in the absence of data clearly indicating otherwise.

Dr. Goldfarb raises the issue of the half-life of 2,3,7,8-TCDD and states that the lower estimates may result from inaccurate sampling and analytical techniques. This criticism is not relevant, however; because of the contradictory data regarding half-life, we took the most conservative approach i.e., assuming that no degradation occurred over time. It should be noted that the half-life of 2,3,7,8-TCDD, regardless of its length, will reduce exposure, possibly substantially, and therefore, by not assuming any half-life at all, our risk assessment assumption for this issue could not be more conservative.

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Thomas C. Chalmers, M.D.
Distinguished Service Professor
Clinical Trials Unit

August 7. 1984

Dr. David Lipsky
Group Manager
Public Health and Chemistry
Fred C. Hart Associates, Inc.
530 Fifth Avenue
New York, NY 10036

Dear Dr. Lipsky:

I am glad to give you the following comments on the report entitled, "Assessment of Potential Public Health Impacts Associated with Predicted Emissions of Polychlorinated Dibenzo-Dioxins and Polychlorinated Dibenzo-furans from the Brooklyn Navy Yard Resource Recovery Facility." To place my contribution in its proper perspective, you should appreciate that I have limited abilities as an expert in the field. I am a clinical epidemiologist, another translation for which is the study of the application of the scientific method to preventive and therapeutic medicine. I am not an environmental toxicologist, although I have learned something about the field from associations with the Division of Environmental Health of the Mount Sinai's Department of Community Medicine, and have served during the last year on a special committee set up to advise the Commissioner of Health about the safety of inhabitants who might move back into the Love Canal area. There are some analogies between the present New York city situation and those deliberations.

First, I want to commend all of you for what I consider to be a superb document. You have included vast amounts of quantitative material with very skillful dissertations on its applicability to the problem at hand. Aside from its obvious usefulness in assisting arrival at a rational conclusion with regard to the proposed waste proposal, it will also serve as a lasting source document of great interest to scholars in the field.

I have only a few minor omissions to point out. I don't believe that you give enough space and emphasis to the examples of long time human exposure to TCDD (Dioxin). I believe that there are now data on long-term follow-up of factory workers to show that the toxicity in humans from doses far in excess of those expected to be encountered in the city is minimal, although the numbers may be small. The data on exposure of residents of the Love Canal are also impressively benign. You can obtain these from Dr. Robert Huffaker of the Department of Public Health in Albany. In essence they reveal that at the time of maximal exposure to hundreds of different chemicals including dioxin, the only creditable health effects were a diminution in birth size and some very vague symptoms which could have been related to worry as much as exposure. The doses to which some people living in the immediate vicinity of the Love Canal were exposed is very much greater than the life-long exposure expected to result from the incinerators. Although the answer will not be forthcoming about long-term oncogenic effects, there is certainly no evidence as yet of any life-threatening effects.

In the section on relative risks, I believe some data could be given on the effects of smoking. I recognize that this is for the large part voluntary, but on the other hand there are some recent data on passive exposure to cigarette smoke which I suspect reveal a hazard greater than that calculated from the incinerators.

I also have missed some discussion of the relative potential health hazards of not having the incinerators and continuing to dispose of wastes by burning in less safe apparatuses, by burying as at the Love Canal, or by dumping out to sea which we all recognize could eventually be a real health hazard for the whole world.

Finally, I am a little bothered by the fact that the report talks about one incinerator only at the Brooklyn Navy Yard and yet the newspapers mention the fact that five or six are planned for the New York area. Should not the effects of these be considered?

In summary, it is a job well done and the people can be assured that the possible increase in risk from the Brooklyn Navy Yard facility is so minimal that the city should proceed forthwith to tackle this very difficult problem by starting construction.

Sincerely yours,

Thomas C. Chalmers,
Distinguished Service Professor

DOUGLAS M. COSTLE

COMMENTS

on the July 1984 Draft Report:

Assessment of Potential Public Health Impacts

...from the Brooklyn Navy Yard Resource Recovery Facility

prepared by Fred C. Hart Associates, Inc.

These comments address the July 1984 Draft Report on the Assessment of Potential Public Health Impacts Associated with Predicted Emissions of Polychlorinated Dibenzo-Dioxins and Polychlorinated Dibenzo-furans from the Brooklyn Navy Yard Resource Recovery Facility from the viewpoint of public policy decision-making involving risk assessments.

A central question in judging a technology -- whether a manufacturing process, a resource recovery facility, landfilling (conventional or chemically-stabilized), a high-temperature incinerator, etc. -- is not whether it is risk-free, but rather whether the degree of risk presented is acceptable. As our knowledge of analytical chemistry grows, we can detect chemical substances at ever lower concentrations: measurements in parts-per-billion are as routinely possible today as were measurements in parts-per-million a decade ago; measurements in parts-per-trillion may soon be commonplace. In some cases the substances we are now finding are "new" -- i.e., they are synthetic compounds that have only been introduced in the past half-century. In other cases, we are discovering naturally-occurring substances that we either never knew existed, or whose presence in certain places or in certain concentrations was unsuspected at previous limits of detection. Increasingly, therefore, we find (potentially) hazardous chemicals, often in trace amounts, in products or processes related to our society's technologically-dependent living patterns.

The degree of risk deemed acceptable becomes, therefore, ultimately a societal judgment, expressed through our political and social institutions. Our best scientists and their most careful studies can only describe for us the potential nature and outcomes of such risks. Their information and judgment(s) become one more tool -- often a critical one -- in determining how to manage such risks. Sound risk assessments precede sound risk management.

From this perspective, two questions arise in evaluating a risk assessment document: (1) how well has it defined/described the potential risk(s), and (2) how well has it identified underlying assumptions so that we may judge their validity?

The following comments on individual chapters accordingly address these issues of descriptiveness and identification of assumptions from a policy evaluation standpoint rather than from that of a scientific or engineering review.

The Executive Summary, in addition to serving -- quite adequately -- its traditional role of consolidating the report's major findings, is unusually accessible to an interested lay reader who wants a quick overview and explanation of lengthier, more technical materials. Reports like this too rarely bother to explain what "congeners," "isomers," "promotors," or "initiators" are, or the basic chemical structure that differentiates compounds. Here this basic information is succinctly incorporated, giving the non-science-trained reader a framework for the findings and comparisons. The Summary is clear and readable; the assumptions (cf. pp. 13-14) are defined well enough to give a useful context for evaluating the subsequent description of the study results.

In Chapter 1, the explanation of the use of extrapolation in risk assessments is helpful; the identification of safety factors (p.1-6) is particularly good, not only in the description of the conservatism implied but (from the viewpoint of public health concerns) in the selection of the set of factors.

Chapter 2's discussion of the technical aspects (chemical structure and properties, dioxin formation and half-life, pathways, etc.) is useful. Again, the explicit statements of basic facts and findings (cf. pp. 2-1,2, 2-12, and the summary on p. 2-18) are very helpful, as are the explanations of problems with human toxicology studies (p. 2-19) and acute lethality results (p. 2-21). The sections on human health effects are less definitive -- in large part, it seems to me, because the data are less definitive and more subject to varying interpretations. The summary section (pp. 2-38,39) may well be as conclusive as it is possible to be without over- or under-stating the various study results; these paragraphs are therefore likely to be less satisfactory for a reader looking for open-or-shut findings, but they are within the field of potential results generally described by a careful risk assessment. Risk assessments, after all, provide information, not answers.

Chapter 3 on dioxin incineration emissions is, again, useful for the reader attempting to learn about the generation and control of these pollutants through the combustion process. Particularly worth mentioning is the discussion of several theories of dioxin formation and the variations in combustion parameters and products. These descriptions suggest the range of considerations necessary in determining effective controls, from source/generation through process/condition controls to pollutant collection devices. Other panel members will undoubtedly comment in technical detail on the specific design, emission rates, and control feasibility for the facility as presently proposed/designed. From a non-engineering point of view, I find that these sections provide a good general explanation of the project and the technical engineering issues of concern in this report.

Like the data in preceding chapters, the exposure assessments in Chapter 4 are calculated conservatively, in that all three of the likeliest pathways -- inhalation, ingestion, and dermal exposure -- are evaluated and their (potential) contributions allowed for. Here again, the assumptions -- which are necessarily theoretical and numerous -- are appropriately identified, along with some indication of their conservative application.

Chapter 5, the risk assessment itself, is of course the centerpiece of the report. The content and method of development described on p. 5-1 is straightforward and adequate; it provides two, rather than a single, useful risk estimates. The discussion of the limits of the risk assessment process on pp. 5-2 and 3 is very important, including the caveat that the (appropriate, I believe) consistent application of the most conservative assumptions typically results in a higher-than-likely prediction of actual risk. Such potentially over-large estimates of possible hazard are too often misunderstood as indications of unacceptable risk, or even -- sometimes wrongly -- promoted as sole determinants of acceptability. The closing sentence of the section on p. 5-3 describes the proper context for evaluating the numerical values derived from the risk assessment process: "These results of a risk assessment are then used for risk management purposes, to judge whether the upper bound of risk levels are acceptable in comparison to any proposed benefits."

The description of ADIs, NOELs and extrapolation techniques provide good background for the key explanation (cf. pp. 5-8ff.) of the different ways that public health agencies have interpreted data on carcioginicity and the derivation of the toxic equivalency numbers used in the report. All of this discussion is prelude to the explanation of current standards and guidelines (pp. 5-16 to 5-25). These guideline summaries contain succinct identifications of assumptions and limitations (cf., e.g., pp. 5-18 and 5-21). More critical are the report's own adopted limitations set out on pp. 5-25 through 5-27. These latter assumptions seem reasonable and well within accepted criteria for these types of calculations; if anything, they probably err on the side of conservatism -- the bias most protective of public health. Accordingly, the estimates of exposures (intake through the previously described pathways [inhalation, etc.]) in the following pages are also likely to be conservative -- i.e., high. Lastly, the summary of this section (pp. 5-51 to 5-53) presents a clear and readable distillation of the somewhat complex (for lay readers) calculations in the latter half of the chapter.

While the first three sections of Chapter 6 are essentially a reprise of parts of Chapter 5, they are particularly valuable as a succinct statement of the judgment factors (assumptions) and some of the relevant studies/methodologies used to derive the numerical values that are the end result of this risk assessment process, especially for the lay reader who desires an overview and summary of these materials.

The Dowd summary quoted on p. 6-5 encapsules in a single paragraph the general numerical risk assessment parameters that are used to trigger review or regulatory action in federal Environmental Protection Agency programs. As noted, these levels vary somewhat among programs (e.g., drinking water, air). The variations depend on many factors, including Congressional mandates specified in program legislation -- for example, just one statute (the Clean Air Act) requires an "adequate margin of safety" in establishing one kind of standard (§. 108) and an "ample margin of safety" for establishing another kind (§. 112). Such legislative instructions, along with other variables such as the adequacy of data bases and the limits of measuring/modeling abilities, obviously result in variations in calculated numerical values, for which the Dowd summary furnishes a good sense of comparative practices. Because EPA's statuatory charges to protect public health encourage the Agency to adopt assumptions weighted toward conservatism, the Agency's general risk "trigger numbers" outlined here are often criticized as overly stringent. On the other hand, other health-protective regulatory bodies (NYSDOH is cited) consider EPA's levels too lenient, especially for target populations, and opt for more stringent criteria. As the report quite accurately observes, "The issue of acceptable risk levels continues to be an area of considerable controversy" (p. 6-6).

Lastly, two other sections of Chapter 6 deserve to be called to the reader's attention, namely, the paragraph on non-dioxin--related risks (p. 6-6) and the following brief section on overall cancer rates, especially pp. 6-6 through 6-8. While not traditionally a part of a classic scientific risk assessment, the table on estimated death risks for New York State residents (p. 6-7) can give a reader some sense of perspective for evaluating the acceptability of the risks estimated to be presented by this proposed resource recovery facility.

The preceding comments may appear less critical of this draft risk assessment than might be considered appropriate from a reviewer who has explicitly been asked to critique it. Please note, however,that my remarks in praise of the report -- for its readability and general informativeness -- do not so much reflect an endorsement of its scientific or technical thoroughness or accuracy: I defer to other reviewers on these subjects. Rather, I have evaluated the draft as it meets criteria evolved from my experience as a policy- and decision-maker. In this capacity, what I look for in a risk assessment is a well set out evaluation -- using clear, understandable language and concepts -- of what the problem is, what ranges of risk it presents, and the data and assumptions used to quantify the numerical risk values.

This draft report basically satisfies these criteria. Based on the understanding it provides of the degree of risk associated with the proposed facility -- well within current accepted public health protection parameters -- a decision-maker can proceed to the next step of judging the possibility and desirability of managing the risks presented. And interested readers simultaneously have in the report a basis for forming their own opinions of the acceptability of these risks.

8/27/84

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Comments on "Assessment of Potential Public Health Impacts Associated with Predicted Emissions of Polychlorinated Dibenzo-dioxins and Polychlorinated Dibenzo-furans from the Brooklyn Navy Yard Resource Recovery Facility"

by Theodore D. Goldfarb

General Remarks

As pointed out repeatedly in the Fred C. Hart Associates' report, the task of assessing the potential health impact of PCDD and PCDF emissions from the proposed BNYRRF is a complex endeavor requiring the use of many assumptions and estimates. Despite the numerous recent studies on a wide variety of dioxin exposure problems, including many that have focused on incinerator emissions, key questions remain unanswered. Insufficient data exists to permit a precise prediction of either the expected dioxin and dibenzofuran emissions or the public health consequences of an assumed level of emissions.

The principal conclusion of the report is that the likely PCDD and PCDF emission levels constitute a health threat that is too low to warrant additional review or action to further reduce the risks. This conclusion appears to be at odds with some of the recommendations in recent generic studies such as the Canadian "Report of the Ministers' Expert Advisory Committee on Dioxins" and the California Air Resources Board study of "Air-Pollution Control at Resource Recovery Facilities." The Canadian study identifies municipal and industrial incineration as the largest source of environmental dioxin contamination and recommends a comprehensive program to minimize such emissions. The California Study suggests the use of dry scrubbers in addition to the baghouse filters as a method of further reducing toxic organic effluents. In addition another recent assessment of the risks of dioxin and dibenzofuran emissions from proposed New York City Incinerators, by B. Commoner, K. Shapiro and T. Webster, predicts a considerably greater cancer promotion threat than the Hart study, and recommends remedial action.

The data used in the Hart study, does not differ appreciably from that used in other technical assessments of the PCDD and PCDF emission hazard. The presentation of the facts available in the literature is generally thorough and complete. A commendable effort is made to estimate public exposure resulting from ingestion of accumulated dust fallout as well as the usual calculation of estimated inhalation exposure. What distinguishes this and those other studies which have concluded that the PCDD/PCDF risk is minimal from those that consider it a serious potential health threat are the assumptions and value judgements used in arriving at the conclusions.

After carefully reviewing the present study it is my conclusion that the BNYRRF presents a significantly greater potential health threat to the public as a result of PCDF/PCDD emissions than is claimed in the report. In view of the fact that this is only the first of eight such facilities planned for New York City and that other sources of airborn dioxins and dibenzofurans such as hospital incinerators, industrial furnaces and existing solid waste incinerators will continue to operate, I believe that every effort must be made to reduce such emissions to an absolute minimum. If the City decides to procede with the building of resource recovery plants, after reviewing other means of disposing of its municipal waste, it should incorporate the best available control technology to limit airborne effluents and it should find sites for these plants that will result in less public exposure than the Brooklyn Navy Yard. The recent decision by the Department of Sanitation to specify the use of air bags, rather than the less effective electrostatic precipitators to control particulate emission is a step in the right direction. The air bags should be coupled with a dry scrubbing system. This will have the dual advantage of drastically reducing the hazardous acid emissions, presently ignored by the Department of Sanitation, as well as providing the potential for significant further reduction in toxic organic emissions including PCDD and PCDF. In a recent technical report Dr. W. Shaub, of the National Bureau of standards, has provided theoretical support for the proposal that PCDD and PCDF can be contained by an appropriately engineered scrubbing system. I urge the City of New York to fund the experimental research studies recommended by Dr. Shaub which could provide the data needed to adjust the scrubbing conditions to provide maximum containment of the toxic effluents. The City should also urge the State to promptly promulgate emission standards for resource recovery plants, or it should have its own Departments of Environmental Protection and Public Health promulgate such standards. Without such standards there is no guarantee that the plant will be operated properly even if the laudable recommendations in the Hart report for the inclusion of technology to permit continuous monitoring of key operating conditions is accepted by the Department of Sanitation.

My principal criticisms of the assumptions and methods used in the Hart study are as follows:

- The data used in estimating the projected levels of PCDD/PCDF emissions from the BNYRRF is from a single set of measurements on one similar facility in Chicago augmented by data from another such plant in Switzerland. It is acknowledged that data of other incinerators, including those designed for resource recovery, indicate emission levels that are tens to thousands of times higher. Not enough is known about the way PCDD and PCDF are formed in incinerators to justify rejection of these data on the grounds that the conditions may have been different than in the Martin type furnace planned for the BNYRRF. This choice of a low set of emission values affects every other phase of the risk calculation and seriously undermines the credibility of the results.

- The report repeatedly refers to the "conservatism" of the assumptions and methods used and suggests that the actual hazard potential is likely to be much less than what is purported to be a "worst case" scenario. In fact many of the references to conservatism are either completely inappropriate or involve only a small likely overestimate of the hazard. Considering the fact that several of the assumptions and methods may underestimate the potential risk by orders of magnitude (see the preceding criticism and those that follow) it is hardly credible to refer to the overall procedure as a "worst case" scenario. Examples of assertions of conservatism with which I disagree are:

(1) The use of a multiplicative factor to estimate the carcinogenic and other toxic effects of all PCDD/PCDF ~~cogners~~ isomers based on data for 2, 3, 7, 8-TCDD. The failure of other assessments to include this factor is a serious error. The inclusion of a reasonable factor is not "conservative" nor is it a "worst case" assumption.

(2) The claim that the most conserative cancer risk assessment is included. The recent report by Commoner et al. uses an apparently rational scientific method of estimating cancer risk for promoters like TCDD that leads to considerably higher values than the methods used in the Hart report.

(3) The use of 24 hour, 70 year exposure at the point of maximum impact. The dispersion model predicts levels of airborne effluents that are close to the maximum level extending over a large fraction of the heavily populated metropolitan area. Thus this assumption is only slightly conservative.

- The model used to estimate the fallout of particulate matter laden with PCDD/PCDF fails to account for agglomeration of small particles with larger ones or to take account of the effect of building structures and elevated terrain in promoting fallout. It is asserted without justification that this is likely to result in only a small error. In fact the small particles that are assumed to remain suspended carry greater than 98% of the projected PCDD/PCDF emissions. If only a small fraction of these suspended particles are incorporated into the larger, often moist particles that regularly precipitate out of New York City air or if they deposit as a result of repeated impact with elevated structures or the walls of enclosures the result will be an increase in the estimated deposition of dioxins and dibenzofurans that could increase the exposure from ingestion and dermal exposure many-fold. Since the upperbound estimate makes the ingestion mechanism the principle route of exposure the result is an additional serious potential underestimate of risk.

The criticisms detailed above, and those listed below in the section on Specific Comments are not intended to imply that those who prepared the H~~un~~art report were lacking in competence or are guilty of a willful attempt to underestimate the risks. In a situation where many assumptions and estimates must be made it is inevitable that the subtle pressures that operate on any client consultant will result in choices that favor the outcome desired by the contractor of the consultant's services. In this case the contractor, the Department of Sanitation, was a very visible presence, reviewing and commenting on the consultant's efforts on an ongoing basis. It is therefore to be expected that, given the uncertainties involved, the consultant's conclusion and the conclusion contained in the Preliminary Draft Environmental Impact Statement (also prepared under contract to the Sanitation

Department) is that the PCDD/PCDF emissions from the BNYRRF will result in "acceptable" health risks. If the City desired a more independent assessment of the potential risks it would have been wiser to ask an agency with less of a vested interest such as the New York State Department of Health, to oversee the study.

It is only reasonable to expect independent environmental scientists and the general public to make value judgements that differ from those of a City Agency charged with doing a particular job within budgetary constraints. In this case the Sanitation Department is also contending with vendors of resource recovery equipment who have a large vested interest in resisting attempts to increase the cost of their products by requiring additional safety features. My own judgement is that the added cost of additional PCDD/PCDF controls and of acid gas control is clearly justified by the potential (though necessarily speculative due to ~~our~~ limitations of available scientific data) health threats posed by these effluents.

Specific Comments

Section	Page	Comments
1.4	1-6	Several criticisms of the list of "conservative assumptions" are included under General Comments above. The remaining "conservative" safety factors do not appear to include any assumptions that would unrealistically overestimate likely risk. The assumptions of equal indoor and outdoor pollutant levels and of no PCDD losses due to volatilization or degradation should result in less than a doubling of risk estimates.

1.4	1-7	As indicated above, it is incorrect to assert that the calculations represent an "upper limit" to risk.
2.1.3	2-6	Although it is true that recent papers by Somers and Douglas, Hasselriis, Lauber and others indicate a correlation between poor combustion efficiency and high PCDD/PCDF levels when examining data from specific facilities, attempts by Niessen and others to develop specific relationships between particular operating parameters and emission levels that apply to all facilities shows that the information currently available is inadequate for this purpose.
2.3.1	2-12	The literature does contain estimates of the environmental 1/2-life of 2,3,7,8-TCDD ranging from 0.5 to 12 years, but the earlier, lower estimates have been criticized as resulting from inaccurate sampling and analysis techniques.
2.3.1	2-20	The statement that a linear non-threshold model is believed to overestimate risks for cancer promoters is by no means universally accepted. Commoner, Shapiro and Webster have developed an alternative analysis that results in a larger risk value than the usual linear model based on the assumption that dioxins are cancer promoters and that the ratio of increased cancer incidence to background incidence should be proportional to promoter exposure.
3.2.2	3-2	Recent results from Canada strongly support the theory that at least a major fraction of PCDD/PCDF is formed

by a de novo mechanism. Mass balance analysis has shown that in the case of two specific facilities in Ontario more PCDD/PCDF is emitted than was initially present in the waste input.

3.2.2 3-5 The negative results of the addition of PVC to the waste input of a resource recovery facility in France by Karasek does not necessarily indicate that removal of chlorinated plastics would have little or no effect on PCDD/PCDF emissions. France has one of the highest percentages of chlorinated plastics in the waste stream. If there was already excess chlorine present adding another source would probably not have much effect. Experiments should be performed on a variety of waste streams to determine the effectiveness of PVC removal with regard to controlling chlorinated organic effluents. PVC removal would also reduce the HCl gas emission problem.

3.3 3-13 The existence of instruments to measure combustion process parameters, in the absence of standards that specify minimal operating conditions and an effective system for independent monitoring of the operations, does not assure that efficient combustion will be maintained.

3.3 3-14,15 As indicated in the General Comments section I consider the rationale offered to ignore the much higher PCDD and PCDF emission levels from other

		incinerators to be a very serious defect in the analysis. Even if, as has not been adequately proven, Martin Units are intrinsically capable of producing lower emission rates, it is by no means certain, based on industry experience, that the plant will be continually operated at optimum conditions.
3.4	3-16	I would like to see an economic and technical analysis that shows that the goal of effective resource recovery corresponds to the "optimization of combustion efficiency" in a manner that minimizes PCDD/PCDF emissions.
4.3	4-8	As noted in the General Comments Section I consider the failure of the ISC model to account for particle agglomeration and the impact of elevated terrain or buildings to be a serious potential source of error.
4.4	4-16	Comparison of PCDD/PCDF with lead levels indoors and outdoors may be misleading. Much of the outdoor lead comes from automobile exhausts and settles rapidly on roadways. This is clearly different from a gaseous or microparticulate stack emission.
5.3.1	5-17	While it is true that the present EPA appears to consider cancer risk levels as high as 4.6×10^{-5} to be "minimal", previous EPA officials did not always share this view. The EPA has also failed to publicly announce that it considered 46 potential extra cancer deaths per million people to be minimal. If they did so it is highly unlikely the public would accept that

		assessment.
App. C	C-4	The assumption that if the furnace supplier operates the unit, problems are likely to be minimal is contrary to the experience of those who are familiar with the operation of the Hempstead RRF which involved a similar arrangement.
C	C-7	The assertion that dry scrubbing must be done with an expensive "specialty chemical" is not necessarily true. There is evidence that the recycling of fly ash as a dry scrubbing material might be effective. Also the characterization of the dry scrubber/filter fabric combination as untested" is not accurate. By the time the City's first recourse recovery facility is completed there should be considerable experience with such systems in Japan and California.

University of Arkansas for Medical Sciences

4301 W. Markham
Little Rock, Arkansas
72205

August 8, 1984

Dr. David Lipsky
Fred C. Hart Associates, Inc.
530 Fifth Avenue
New York, New York 10036

Dear Dr. Lipsky:

I have reviewed the Report entitled "Assessment of Potential Public Health Impact Associated with Predicted Emissions of Polychlorinated Dibenzo-Dioxins and Dibenzo-Furans from the Brooklyn Navy Yard Resource Recovery Facility." I have the following comments concerning this report.

The toxicity data for Polychlorinated Dibenzo-Dioxins (PCDDs) and Polychlorinated Dibenzo-Furans (PCDFs) are adequately reviewed and accurately assessed. This information has been used to assess the risk associated with predicted emissions of PCDDs and PCDFs from the Brooklyn Navy Yard Resource Recovery Facility (BNYRRF). I agree that the risk associated with the predicted emissions of PCDDs and PCDFs from the BNYRRF are small and well below the risk generally considered acceptable by the United States Environmental Protection Agency for these compounds. I have evaluated all aspects of the assessment of risk for predicted emissions of PCDDs and PCDFs from the BNYRRF and I concur with the modeling and support the conclusion that the BNYRRF can be built with negligible risk to the surrounding community public health. The predicted emissions are conservatively estimated and likely to be overestimated. Therefore, the risk associated with the prediction is also likely to be overestimated. Using a very conservative assessment, there is still a negligible risk associated with the operation of the BNYRRF.

I support the construction and operation of the BNYRRF and have determined it does not increase the risk of the surrounding community to adverse health effects.

Sincerely,

Raymond D. Harbison

Raymond D. Harbison, Ph.D.
Professor and Director of
Interdisciplinary Toxicology

REPORT

Comments on the 'Fred C. Hart Draft Report'
concerning a proposal to operate a Martin-
type incinerator at the Brooklyn Navy Yard.

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Appendix

I. INTRODUCTION

It is proposed to build and operate a Martin-type incinerator to burn municipal solid waste at the Brooklyn Navy Yard. This has aroused public concern illustrated by the circulation of a report prepared by Dr. Barry Commoner and associates (called here "Commoner Report"). The main issues raised in the Commoner Report are that the hazards of incineration have been under-estimated for two reasons. First, seven more incinerators are to be built which will lead to greater flue emissions; and second the hazards associated with dioxin release to the atmosphere have been under-estimated in various ways.

The purpose of this report is to review the 'Fred C. Hart' report, to assess the Commoner Report and to make any suggestions arising therefrom.

II. THE FRED C. HART REPORT

Section 2. The report goes through the relevant properties of dioxins. 957°C would be required for 99.99% destruction of 2,3,7,8-TCDD in an incinerator with a dwell time of 2 seconds; the BNY incinerator has a design combustion temperature of 980°C. The dioxin literature is reviewed accurately and conservatively. An important point is that dioxins disperse through the top foot of soils high in organic matter and down to at least three feet in sandy soils. This will effectively reduce the concentration entering houses as dust.

While the report states that the toxic mechanism is not known it would be useful to discuss Poland's hypothesis and data in more detail since they show little effect of low dioxin levels, and highly non-linear switch-like behavior in receptor binding and enzyme induction, leading to over-estimation when linear extrapolation is used.

Section 3. Dioxins and dibenzofurans can reach the incinerator effluent both by de novo syntheses and from their presence already in MSW. Thus, the most important variables in incinerator operation are waste and incinerator type. For this reason it makes good sense to compare the proposed incinerator with that in Chicago and it is reasonable to base risk estimates on effluent measurements from Chicago NW; which has a similar design and combustion temperature. The discussion of ash particle size and dioxin and dibenzofuran condensation onto ash is thorough and accurate.

Section 4. In this section data are given for particle settling rates and the accumulation of dust indoors. Only 7% of particles actually settle, and these are the largest, while about 10-25% of the outside concentration of another toxin, lead, is found indoors. Thus, it would be very effective to remove more large particles from the stack effluent.

Section 5. This section contains risk assessments and shows that, using the toxic equivalent approach of the Swiss EPA, which is conservative, an excess cancer risk of 0.4×10^{-6} can be calculated. This is far below EPA risk assessments which were considered to show minimal public health risks and which ranged from $8\text{-}19 \times 10^{-6}$.

In this section the calculations, in which contributions from various sources are added, are given. Up until page 5-44 the text is reasonably clear. Numbers are missing at the bottom of that page and on page 5-48. The discussion here shows signs of hurry and is hard to understand; it is not clear where the new risks (p. 5-49) ranging from 2×10^{-8} to 47×10^{-6} come from; similar figures on p. 5-50 are not explained.

Section 6. Risks from other hazards are given for comparison and do, indeed, show the relatively insignificant risk due to a new incinerator.

III. Comments on the Hart Report

The report is reasonably clear and well argued. The weakest sections are around pages 5-47 to 5-50, where relatively high risk estimates are not adequately explained or dismissed. This section is too hurried and has several omissions.

The primary data on the carcinogenicity of dioxins are not, to me, compelling. The results look more like plain sampling error since the number of significant results is well within 10% of the total number of results in the Kociba et al. study. While one might not get far with this argument, since everyone believes they are carcinogenic, it does give one confidence that risk estimates are high, almost certainly by one or two orders of magnitude. Since many other factors have been treated conservatively I therefore agree that the incinerator presents no hazard as it is proposed. However, since it appears that there will be 8 incinerators (see Commoner report) it would also be conservative to consider my recommendations in order to reduce dioxin and fly ash in the effluent. The report should include a discussion of the extra incinerators if they are indeed to be built.

In section 5 it would be appropriate to have a short graphical summary of the results. The section is quite long and confusing.

IV. THE COMMONER REPORT

In general in the Commoner Report accurate data are used but manipulated inaccurately. The main points made, in order, are:

1. There will have to be eight incinerators, burning a total of 21,850 tons/day of MSW.

2. Since it is projected that the first will be in operation by 1989 (i.e. five years after construction starts) a further three will have been begun before experience has been gained from operation of the first.

3. The only significant environmental hazard, with no generally accepted standards, will be the release of dioxins and dibenzofurans from the incinerators.

4. A risk assessment must be made using known emission rates from incinerators already operating.

5. Since the carcinogenicity of only one dioxin, 2,3,7,8-TCDD, is known, toxic equivalents must be calculated for the other groups of dioxins and dibenzofurans.

6. Most of the dioxins and dibenzofurans condense onto fly ash; its dispersal can be modelled. For eight incinerators the maximum deposition of fly ash will be increased by a factor of 3.14.

7. Calculation of the total uptake of dioxins and dibenzofurans by humans must take into account the higher

concentrations at higher levels - e.g. in high rises - and the accumulation of dust in houses which are imperfectly cleaned.

8. Since 2,3,7,8-TCDD is probably a promoter its effect (and the effects of the other compounds) will be a multiplicative one. The factor can be derived from the Kociba et-al data for rat liver tumors. Applying it to the other data the excess cancer risk, in the worst case, turns out to be 421 cases/year for greater New York.

9. Thus the risk of building and operating incinerators may not be acceptable.

The flaws in the Commoner Report are as follows, keyed to its page numbers.

1. (9-10) The best model for the BNY incinerator is a Martin-type incinerator in Chicago, called Chicago, NW. Not only is this the same type as the proposed incinerators, but it burns similar waste. Thus it is highly significant that it releases dioxins and dibenzofurans at the lowest measured rate for incinerators for which adequate data are known.

2. (11-12) The toxic equivalents are calculated in terms of efficency in inducing aryl hydrocarbon hydroxylases; yet this is not known to correlate with carcinogenicity.

3. (14-20) Commoner believes there are no data allowing calculation of the deposition of toxins in houses, and that dust enters with perfect efficacy. There are data (cited in the Hart report) and dust "scrubbed" as it enters, removing some particles. Commoner concludes that exposure indoors is the same as outdoors, but this is known not to be true, a reduction of up to 75% being realistic. In addition he does not subtract the dust accumulating indoors from the total accumulation outdoors. Both errors lead to over-estimates, which have a multiplicative effect in his risk assessment.

4. (22-27) Commoner's most egregious error is to use a single set of data points from the Kociba et. al. study of rats to get a 'factor' whereby the promoting effect of the carcinogens can be calculated. This factor is 16%/lng toxic equivalent/kg/day. Taken over-all the Kociba et. al. data do not show a significant increase in tumor incidence, since some sites show more and some fewer tumors in experimentals than controls, and fewer than 10% of the results show significant differences from the controls. Nonetheless, if the carcinogenicity of 2,3,7,8-TCDD <u>is</u> accepted it is an obvious distortion to use a single ratio, one liver tumor in a control group of female rats and eleven in an experimental group to calculate a factor for risk assessment. From the

data given the ratio could easily have approached one, leading to a very small risk. Indeed, Poland (1982) shows clear thresholds for 2,3,7,8-TCDD binding and enzyme induction, so that linear extrapolation, as done by Commoner, is inconsistent with the promotion effect Commoner assumes.

Thus, the Commoner report errs in several ways. If the Chicago NW incinerator were used as the model the excess risk found, <u>even retaining the other erroneous assumptions</u> and allowing eight incinerators would be about $1x10^{-6}$.

V. RECOMMENDATIONS

The objections raised in the Commoner Report do not appear to be valid and are adequately covered by Fred C. Hart. However, there are several issues crucial to the safe running of one or more urban incinerators, even though U.S. experience to date has been good and does not justify widespread concern. It is vital to:

1. Remove particulates efficiently.

2. Maintain an adequate combustion temperature and dwell time.

3. Monitor particulate emission.

Therefore, it is recommended that the Hart report be modified as suggested and that it would be prudent to:

1. Insert a second stage of electrostatic precipitation to reduce small particulates (below 1.0 m diameter). This may require extra fan horsepower.

2. Maintain combustion temperature at furnace throat as close to design temperature (980°C) as possible.

3. Monitor particulate emission using back-scattering from a laser of appropriate wave-length.

BEST AVAILABLE COPY

RECEIVED AUG 1

RECEIVED AUG 10 1984

University of
Arkansas
for Medical
Sciences

4301 W. Markham
Little Rock, Arkansas
72205

August 8, 1984

Dr. David Lipsky
Fred C. Hart Associates, Inc.
530 Fifth Avenue
New York, New York 10036

Dear Dr. Lipsky:

Attached are some of the errors or omissions I noted in the draft report entitled "Assessment of Potential Public Health Impacts Associated with Predicted Emissions of PCDDs and PCDFs from the Brooklyn Navy Yard Resource Recovery Facility". I have not yet finished and will provide the remaining comments by the end of this week.

Sincerely,

Raymond D Harbison/rec

Raymond D. Harbison, Ph.D.
Professor and Director,
Division of Interdisciplinary
Toxicology

RDH/rec

Equal Opportunity Employer

2-10: 2.2.1-line 3: "As a result dioxins will tend to bind to fatty tissue". Dioxins don't bind to fatty tissue, but are stored or absorbed in fatty tissue. Change bind to concentrate. Bind sounds like a chemical reaction which is not reversible and could be confused with receptor binding.

Kooke, R. et al. 1981 reference is not styled correctly. Too many spaces between lines.

2-11: 2.2.2-line 5-6: Shaub and Tsang (1983) is listed as 1981 in references.

2-12: line 3 - Crosby and Wong, 1977 is 1976 in references.

2-12: 2.3.1-line 2-3: Young 1983 is 1981 in references.

2-12: 2.3.1-line 6: Freeman and Schroy 1984 is Freemen in references

2-13: Empirical formula for 2,3,78-TCDD is not correct.

2-14: line 5: Crosby and Wong 1977 is 1976 in references.

2-14: line 11 and 13: Nestrick et al 1980 is 1981 in references.

2-15: 2.3.3-line 12-13: Matsumura and Ward 1976 is not in reference section.

2-15: 2.3.3-line 15 and line 27: Matsumura et al 1983 is listed as 1981 in the references.

Table 2-4: Crosby et al 1973 is not listed among the references for Chapter 2.
Crosby and Wong 1977 is 1976 in the references for Chapter 2.
Bertoni 1978 is not listed in the references to Chapter 2.

2-17: 2.3.4-line 1 and 17: Thibodeaux 1984 is 1983 in the references.

2-17:2.3.4 last paragraph, line 2: Crosby and Wong, 1977 is 1976 in the references.

2-18: second paragraph, line 3 and 4: Hutter and Philippi, 1982 is 1980 in references.

2-18: second paragraph, line 8: Camoni et al., 1982 is 1980 in the references.

2-19: 2.4.1, third paragraph, line 6: NAS, 1977 reference is not contained in bibliography.

2-20: line 3: Piper et al., 1973 is not contained in bibliography.

2-20: line 4: Fries and Marrow, 1975 is not cited in the bibliography and Rose et al., 1976 and Nolan et al., 1979 are not cited in the bibliography.

2-20: paragraph 4:
Line 2 and 3: Pitot et al., 1980 is not cited in the bibliography.
Line 5 and 6: Kouri et al., 1978 is not cited in the bibliography.
Line 6 and 7: NTP, 1980b and Berry et al., 1978 and 1979 are not cited in the bibliography.

2-21: 2.4.2-line 6-8: This sentence is not clear and should be revised.

2-21:2.4.2- Second bullet, line 3-4: The thymus involutes but what body tissues. There may be wasting or atrophy of body tissues. The terms wasting or atrophy better describe the effects seen for other tissues.

2-21:2.4.2- Third bullet, lines 1-3: The terms dose and dosage are not usually used synonymously with exposure. For example the interval between dosage and death ranged up to 45 days. This would be better style if it read the interval between exposure and death ranged up to 45 days.

Table 2-5: Loomis, Essentials of Toxicology is not cited among references.

Table 2-6:
Third column: Vertibrates is misspelled.
Fourth column: Should be minimum observed dosage.
Fifth column: Should be minimum observed dosage.
Sixth column: Should be minimum observed dosage
Legend: Superscript a: What is acute sensitivity to PCDDs? Should this be acute toxicity? Are all dosages for all toxicities administered by the same route? If not, should be noted.

Table 2-7: LD_{50}s are usually referred to as Medial Lethal Dosages.

2-25: line 17: Toth et al., 1978 is not cited among references.

2-27: line 14: Oliver (1975) is not cited among the references.

2-27: last paragraph, line 2: Holmstedt (1980) is not cited among the references.

2-30: line 8: Wipf and Schmidt, 1983 is not cited among the references.

2-30: 2nd paragraph - last line: Beale, 1977 is not cited among the references.

2-30, fourth paragraph, line 3: 10:10 mixture should be 1:1.

Table 2-10: Poland et al., 1971 is not cited among the references.
Walker and Martin, 1979 is not cited among the references.
Column 3, line 5-6: Should read elevated triglyceride levels, omit and.
Ott et al., 1980 is Ott, 1980 in references. There is no et al.
Column 3, line 14: plaoma should be plasma.

2-32:2.4.4, line 2: Toth, 1979 is noted as Toth et al., in references. Which is correct.

2-33: line 1: .1 ug 2,3,7,8-TCDD kg/b.w.-day should be .1 ug 2,3,7,8-TCDD/kg b.w./day.

Line 4: Squire, 1980 is not cited in the reference section.

2-33: second paragraph, line 3: .071 ug/kg/b.w.-day should be .071 ug/kg b.w./day.

second paragraph, line 9-10: 0.1 ug/kg/b.w. as opposed to 0.7 ug/kg/b.w. should be 0.1 ug/kg b.w. as opposed to .07 ug/kg b.w.

2-33: Human Epidemiology, line 6: Hardell (1977) is not cited in the reference list.

2-33: Human Epidemiology, line 14: Smith et al., 1983 is not cited in the reference list.

Table 2-11: Dose level: T_4 has not been previously used or described.

Table 2-11: Superscript legend e is not used in the table.

2-35: line 4-5: Sarma and Jacobs (1982) is listed as 1981 in the references. Also on line 4 Jacoks should be Jacobs.

2-35: line 7 and 8: Bishop and Jones, 1982 and Olsson and Brandt, 1982 are not cited in the references.

2-35: line 8 and 9: Hardell, 1979 is not cited in the references.

2-35: line 9 and 10: Thiess and Frentzel-Beyme, 1977 is not cited in the references.

File

EMORY UNIVERSITY SCHOOL OF MEDICINE
MASTER OF PUBLIC HEALTH PROGRAM
1518 Clifton Road, N.E. Atlanta, Georgia 30322

OFFICE OF THE DIRECTOR (404) 329-7806

RECEIVED AUG 6 1984

August 2, 1984

David Lipsky, Ph.D.
Group Manager
Public Health and Chemistry
Fred C. Hart Associates, Inc.
530 Fifth Avenue
New York, NY 10036

Dear Dr. Lipsky:

I have reviewed the finalized version of the report which you sent on July 18, regarding assessment of health impacts of dioxin-furan emissions anticipated from the planned Brooklyn Navy Yard Resource Recovery Facility. My comments on the report are given below and are arranged, as you request, in both general and specific categories.

A. General Comments. The report seems to me to be an exceptionally complete and thorough analysis of a most complex public health/toxicologic/engineering issue. It reviews the issues of dioxin/furan properties and emissions, as well as exposure and risk assessment, in their logical sequence and with a realistic appreciation of the strengths and weaknesses of our current knowledge concerning these areas. In particular, the report clearly explains the step-wise assumptions which must be made in such cancer risk assessments. The cumulative conservative effect of these assumptions is especially well conveyed.

I can provide specific evaluations only for the public health/toxicology aspects of the report. In these areas, it appears to me that the report provides an accurate and complete review of pertinent scientific literature and that the conclusions reached concerning risk levels, based on that scientific review, are justified and valid.

B. Specific Comments. The Chapter concerned with dioxin/furan properties clearly appreciates the variability in toxicologic response observed among different laboratory animal species exposed to these organic compounds and the attendant difficulties in extrapolating such findings to the human situation. The review of human data is complete and detailed. Despite the low-dose carcinogenicity and teratogenicity of dioxin in laboratory animals, direct evidence of such effects in humans is lacking. In particular, recent suggestions that dioxin exposures may lead to sarcoma production in humans remain unresolved. Animal data are currently perceived as suggesting that dioxin plays a promoting rather than an initiating role in carcinogenicity.

THE WOODRUFF MEDICAL CENTER

Chapter 3 on dioxin/furan emissions deals with the engineering and chemistry aspects of incinerator technology. Although I cannot judge the details of this chapter, it appears to be a thorough review and assessment. Principal points are the requirement for particular temperature, time, turbulance, and oxygen mixture parameters in effective dioxin/furan combustion, and the need to assess emissions in terms of both gases and particulates when emission control is predicated on a fabric filter.

Exposure assessment (Chapter 4) depends on computerized meteorologic predictions of air concentrations and particle deposition in the New York area. These predictions are obviously critical to subsequent health risk assessments. They inevitably require a series of assumptions concerning eventual dioxin/furan concentrations at the end of dispersion pathways in air, soil, dirt, and dust. The consistently conservative nature of these assumptions is clearly explained. Unfortunately we have no way of knowing in a quantitative sense how great an impact these and other assumptions have on the eventual risk assessment.

The fifth Chapter deals with health risk assessment based on data and assumptions discussed in the preceding chapters. The assessment process involves several further conservative assumptions, each of which is as clearly explained, I think, as the subject's complexity allows. These include some allowance for toxic equivalency estimates, statistical models for cancer risk extrapolation, assumptions regarding maximal or "worst case" lifetime exposure scenarios, and assumptions concerning degree of toxin absorption into human tissue. The resulting estimates of toxic equivalent intakes are then compared with existing regulatory standards and are translated in conservative fashion into cancer risk estimates. These estimates range widely (from about 5 to about 600 excess cancer cases per 100 million population over a 70 year lifetime), depending on particular sets of exposure/extrapolation assumptions.

In the sixth Chapter, these risk assessments are discussed in relation to other aspects of risk-taking and of competing cancer risks and dioxin sources. Such comparisions are unavoidably qualitative, and yet they represent an important consideration when public health policy is at issue and when it is realized that some level of risk is necessary. The particular comparisons presented in this concluding chapter seem to me to be appropriate to the waste incineration issue and to provide some useful perspectives.

Sincerely yours,

Clark W. Heath, Jr., MD
Professor of Community Health

COMMENTS

On Draft Report: Assessment of Potential Public Health Impacts Associated with Predicted Emissions of Polychlorinated Dibenzo-Dioxins and Polychlorinated Dibenzo-Furans from the Brooklyn Navy Yard Resource Recovery Facility by
Fred C. HART ASSOCIATES INC.

GENERAL COMMENTS

This document is one of the best and complete summaries and literature reviews on various aspects of PCDD/PCDF I have seen in the last years. There are no major errors in the sections on Dioxin chemistry, fate, destruction and emissions. As far as the actual risk assessment is concerned, it is important to note that a conservative approach is taken throughout the document ("to err on the side of public health").Where information is absent or conflicting the most conservative assumptions ("worst case") are made. For instance in the case of photodegradation of airborne PCDD/PCDF no reaction (degradation) is assumed although photoreaction of vapour phase PCDD/PCDF is likely to occur, but no quantitative data in real-life situations exist. In summary, the section on risk assessment is done extremely carefully and an attempt is made to include all imaginable scientific factors from modelling and distribution to stability, bioavailability and toxic effects. The various model calculations and large amounts of numbers, however, convey a sense of certainty and security which does not exist. Whilst it is important to stress that the conclusions are in the very conservative range and that noone else could have done any better, glaring gaps in our knowledge (e.g. carcinogenicity of most isomers/congeners) do not allow presentation of precise numbers.

SPECIFIC COMMENTS

Page 3, last paragr.

Congeners differ by the <u>number</u> of attached chlorine atoms. Isomers have the same number of chlorine atoms but vary in their position of attachment. Tetrachloro-Dioxins is better than "tetrachlorinated". The number of attached chlorines vary from one to eight (even if only tetra- or tri- to octa are usually considered). The abbreviations TCDD (and TCDF) and HCDD (HCDF) should be made more specific to T_3CDD (for tri) T_4CDD (for tetra), H_6CDD (for hexa) and H_7CDD (for hepta).

Only groups of PCDDs and PCDFs with the same number of chlorine atoms can be called isomers.

Page 4, lst paragr.

The herbicide 2,4,5-T is not a chlorophenol but a product derived from 2,4, 5-trichlorophenol.

Middle of page.

Insert high between and, and binding, for clarity, thus: low water solubility and high binding affinity....

Page 5, line 4.

Change sentence to: The acute toxicity of different polychlorodibenzo-p-dioxins varies widely....(problem with use of the term isomer).

Last line of 2nd paragr.

Passage in parentheses perhaps better: (and some related chlorinated hydrocarbons), since several groups of chlorinated hydrocarbons such as the solvents are not known to produce chloracne.

Page 8, 2nd paragr.

The problem of volatile (gaseous) PCDD/PCDF is not addressed.

Page 1-5, 2nd paragr.

lst sentence incomplete.

Page 2-1, line 8 of text.

Use the term herbicide rather than pesticide.

Line 14.

"PCDD and PCDF have also been detected in emissions from combustion sources, primarily municipal and chemical waste incinerators". Municipal incinerators are likely major sources of these compounds.

4th line from bottom.

The congener class of TCDD has 22 isomers. Table 2-1 lists all possible chlorodibenzo-p-dioxins.

Table 2-2 is a list of abbreviations for various chlorodibenzo-p-dioxins (avoid the use of "homologue" which is reserved for series of compounds differing by methyl groups).

Page 2-4.

Exchange homologue for congener in title.

Page 2-6.

First three points: Exchange homologue for congener.

Page 2-8. 1st paragr., last sentence.

Recent results make it likely that more PCDD/PCDF are in the vapor phase than previously assumed.

3rd paragr.

3rd sentence is redundant.

Page 2-9, 2nd last sentence of paragr. 2.

Other samples showed no detectable level of TCDD and only 14 ppt OCDD.

Page 2-10, 3rd paragr.

Under real environmental conditions photochemical formation of PCDD is unlikely.

Last paragr....Dioxins will be found in fatty tissue.(not bind)

Delete "isomer" after PCDF.
Solubility in organic solvents does not necessarily increase with higher chlorine content of the PCDD molecule.

Page 2-11, 1st paragr.

Rather than bind strongly use ...adsorbed onto...

3rd paragr.

Except for the last sentence, this paragraph does not give usable information based on data.

Last paragr., 1st line. delete "harsh".

Page 2-12, first lines.

"Dioxin also will undergo photoreductive dechlorination...". This is the general mechanism for photoreaction.

4th point from bottom of page.

Why is temperature the driving force for the transport of TCDD into the soil column?

3rd point from bottom.

For what climatic conditions do these statements apply?

Page 2-13.
It should be realized that most data shown in table 2-3 give little information for predicting environmental behavior.

Page 2-14, 1st paragr.

Volatilization of PCDD/PCDF from fly ash may be quite different to volatilization from superficially-contaminated soil.

Table 2-4.

Photodegradation data for only 2,3,7,8-TCDD are given (no other PCDD or PCDF, which would be relevant to mixtures as they occur in incineration effluents).

Page 2-3.

The sentence about the de novo formation theory does not accurately convey the statements of Choudhry et al. It should read ...such as a variety of organic compounds and inorganic chloride ions.

Page 3-7, 2nd paragr.

This does not make sense. Most information (including combustion kinetics) originate from laboratory studies, data are then reported in the literature, and retrieved by literature searches.

Last paragr. delete: (i.e. does not burn easily).

Page 3-15.

Section 3.4 is not really about "Rates of Dioxin Emission from Incinerators".

Page 3-31.

Much of the relationship between temperature and destruction efficiency can only indicate trends and certainly cannot be quantitatively transferred from one incinerator to another.

Page 3-32, 1st paragr.

Where are the data to support the statement: ... a significant portion, if not all, PCDF and PCDD emission from incinerators are adsorbed onto fly ash."

Page 4-4, last full paragr.

Frequently in the document reference is made to volatile vs adsorbed PCDD/PCDF; since lower temperatures undoubtedly would favour adsorbtion, reduction of gas temperature in the bag-house section should increase retention of PCDD/PCDF.

Page 5-2, middle of page.

I don't think it is justifyable to use information on the bioavailability of PCDD adsorbed (not absorbed) to soils to extrapolate to fly ash - the binding mechanism and thus availability may be vastly different.

Page 5-18.

I cannot possibly agree with your assumption that carcinogenic and reproductive effects of all TCDD are the same as that of 2,3,7,8-TCDD on the one hand and that you neglect all other PCDD/PCDF on the other. Whilst the overall effect of these shortcomings may indeed cancel each other it is not an elegant procedure considering all the care you have taken in the other steps.

Page 5-31. 5.5.3.3, line 6.
.... a mixture of two HCDD isomers.

Page 5-33, line 14.

Only two isomers....have been tested as a mixture and these compounds were shown to be carcinogenic (to my knowledge no other HCDD have been tested).

Page 5-38/39.

Table 5-9 does not list data on gastrointestinal absorption of PCDD/PCDF from fly-ash. Data by van den Berg et al. (1983) suggest that uptake/retention from fly ash to be much lower than the 50% up mentioned in the Table.

Page 5-50.

The Ontario Ministry of Labour suggests that 2,3,7,8-TCDD acts as a promotor. This, presumably, is based on some data which should be cited.

Page 5-51.

Several safety factors were incorporated into the assessment to ensure conservatism. There is no quantitative measure of conservatism at each step. It would be more transparent if average assessment parameters were chosen and then one conservative but visible safety factor applied.

Appendix C-2, 2nd paragr.

... removal of the plastics may not enhance combustion or <u>reduce</u> PCDF and PCDD emissions.

Appendix C-3, top.

The most efficient way of reducing PCDD/PCDF formation may indeed be removal of chlorine; this, however, is not easily attained in a conventional waste combustor.

Center page.

A cautionary "PVC itself is a <u>significant</u> precursor" may be in order.

OPERATING CONTROLS

Whilst there is no doubt that the Martin system is a modern, efficient system, there is no comparative, quantitative and scientifically sound data available to indicate that this incinerator will emit, in principle, less PCDD/PCDF than another design run under optimal conditions. Eventually, only a constant monitoring program can ascertain low emissions. This monitoring will have to be for PCDD/PCDF.

Since to date no correlation of low PCDD/PCDF emission with operating parameters have been consistently found, except that higher PCDD/PCDF levels can be expected at low operating temperatures, PCDD/PCDF will have to be monitored and not a surrogate parameter.

Bayreuth, August 2, 1984

O. Hutzinger

RECEIVED AUG 10 1984

1441 Oak Manor Drive
Fayetteville, AR 72701
August 6, 1984

Dr. David Lipsky
Fred C. Hart Associates, Inc.
530 Fifth Avenue
New York, NY 10036

Dear Dr. Lipsky:

I have reviewed the final version of the dioxin report entitled, "Assessment of Potential Public Health Impacts Associated with Predicted Emissions of PCDDs and PCDFs from the BNYRRF." This letter constitutes my written comments, both general and specific.

1. General characterization of the overall report.

My general impression of the thoroughness and completeness of the report is very good. The peer review panel assembled by FCH was complete in the sense of the range of expertise represented. There was not much overlap of expertise, but all areas were covered. My function was in the area of environmental fate. I have been on review panels involving dioxins in which there were several individuals with similar expertise. Nevertheless, the document in this regard is very thorough and up-to-date.

The general body of knowledge on environmental fate of dioxins has been consolidated into several key documents. Several years ago the information was scattered and large panels were needed to provide assurance that all aspects were covered. These large panels are not necessary now due to the availability of extensive review documents on dioxins.

New reports of laboratory studies, field studies, models, studies, etc., were presented at each of the meetings held at FCH on Feb. 28 and April 29. These have been incorporated into the report so that it is complete to this moment in time.

The report is well written and presents a faithful reflection of the original manuscripts of experimental and research findings. Again, my comments are with respect to the environmental fate aspects that involve major portions of Chapters 2, 3, and 4. Those particular sections were 2.1, 2.2, 2.3, 3.1, 3.2, 3.4, 3.5, 3.6, 3.7, 3.8, 4.1, 4.2, 4.3, 4.4, and 4.5.

The flow of information in the report proceeds in a very logical order. The building of facts from properties of dioxins to emissions to exposure to risk is very ordered and compartmentalized. This has assured a high degree of completeness. This format provides an easy route from fact to assumption to conclusion.

From the point of view of environmental fate the assumptions adopted to arrive at concentration levels, both for dioxins in (all) gaseous and (all) particulate form, are very conservative in my estimation.

2. Detailed comments on specific aspects.

Page 2-13, Table 2-3. The vapor pressures reported here are apparently much too high. Recently measured values (Freeman and Schroy, 1984) suggest 10^{-9}mm Hg as more reasonable at 25°C. If this data is correct, then under ambient conditions most of 2,3,7,8-TCDD will be associated with the particulates. If the data in Table 2-3 is in fact correct, then the converse may be true; a significant fraction of 2,3,7,8-TCDD is in the vapor phase.

Page 2-15, Line 5. I am not sure this is correct interpretation of the photolytic degradation data I am aware of. It is my understanding that a surface, like silica, must be present and the sorbed species undergoes degradation on this surface in the presence of sunlight.

Page 3-23, Paragraph 2, Line 1. "This suggests that PCDF and PCDD compounds . . ." may be better wording. There has been no vapor/solid sorptions studies with 2,3,7,8-TCDD or related compounds to indicate fact.

Page 4-6, Section 4.3, Deposition Model. It is my opinion that the deposition model prediction is one of the weak aspects of the exposure analysis. The authors state on page 4-8 that, "The model is not equipped to handle terrain features or elevated receptors when calculating deposition, and the model is not able to account for any physical transformations or change in particle size occurring in the atmosphere. Therefore, some inaccuracies may be introduced due to flow obstruction by buildings, and by particle changes. However, the inaccuracies are expected to be minor."

I think it is likely that the deposition rates are higher than the model (ISC w/ reflection) predicts. Reflection coefficients do not account for the reduction in turbulence caused by buildings. In effect, buildings act as a screen to slow the wind, and as a consequence more fines drop out. Wind screens, made of thin slats, are a common device used to cause controlled snow deposition. The present state-of-the-art deposition models do not account for this factor; however, the many conservative assumptions in the particle exposure model should more than compensate for this underestimation of the deposition rate.

<u>Page 4-18, Line 8 from bottom</u>. It is an extremely conservative assumption to neglect trnasformations, volatilization, chemical degradation, biological degradation, resuspension and reentrainment.

Sincerely,

L. J. Thibodeaux

RECEIVED AUG 8 1984

NEW YORK UNIVERSITY MEDICAL CENTER
A private university in the public service

Institute of Environmental Medicine
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ANTHONY J. LANZA RESEARCH LABORATORIES AT UNIVERSITY VALLEY
LONG MEADOW ROAD, STERLING FOREST, TUXEDO, N.Y. 10987
MAIL AND TELEPHONE ADDRESS: 550 FIRST AVENUE, NEW YORK, N.Y. 10016

August 3, 1984

David Lipsky, Ph.D.
Group Manager
Public Health and Chemistry
Fred C. Hart Associates, Inc.
530 Fifth Avenue
New York, New York 10036

Dear Dr. Lipsky:

In response to your letter of July 18th, I have reviewed the July 1984 Draft Report entitled "Assessment of Potential Public Health Impacts Associated with Predicted Emissions of Polychlorinated Dibenzo-Dioxins and Polychlorinated Dibenzo-furans from the Brooklyn Navy Yard Resource Recovery Facility", and I am submitting my comments below, as requested.

<u>General Evaluation</u>

In general, I consider the report to be well-written, careful, thorough, accurate, and consistent with the current state of the art in toxicological risk assessment. I endorse its methodology, assumptions, and conclusions as scientifically appropriate in our present state of knowledge.

<u>Specific Comments</u>

Page 5, 3rd paragraph, line 5: the word "contradictory" should be replaced by "inconclusive".
Page 12, 3rd paragraph, line 3-5: this sentence seems to be incomplete.
Page 15, 3rd paragraph, line 4: I would suggest deletion of "very safe" since the term is ambiguous.
Page 15, 4th paragraph: It would be instructive to estimate the number of years the BNYRR could be expected to operate before inducing a case of cancer; e.g., if the maximally exposed population numbered 1000 persons, the risk estimate implies that thousands of years would elapse before a case of cancer attributable to the BNYRR would occur in this population.
Page 17, penultimate line: I would suggest deleting the word "many" and rewording to read "...generally found by..."
Page 2-20, 3rd paragraph, line 2: I would suggest deleting "in one of two ways" and replace with "through initiation or promotion of tumor formation".
Page 2-20, 3rd paragraph, line 6: I would suggest inserting "some" before "initiators" and "at high doses, however," after "capable".

Page 2-20, 4th paragraph, 1st sentence: I would suggest rewording to read, "Although 2,3,7,8-TCDD is carcinogenic to animals, it is not clear whether it can act both as an initiator and as a promoter of carcinogenesis".

Page 2-35, 2nd paragraph, line 1: I would suggest inserting "possibly" before "associated".

Page 2-35, 2nd paragraph, lines 2-3: "Hodgkin's" is misspelled.

Page 2-36, 2nd paragraph, last line: I would suggest deleting "enough".

Page 2-39, 2nd paragraph, line 5: I would suggest inserting "in humans" after "sarcomas".

Page 5-1, lines 6-7: I would suggest rewording to read "the relationship between the two levels indicates the magnitude of risk...".

Page 5-1, last line: I would suggest replacing "criterion" with "indication".

Page 5-3, 2nd paragraph, last sentence: I would suggest rewording to read, "A conservative assumption is one that increases the estimated hazard to public health".

Page 5-4, 5th line: I would suggest replacing "carcinogenesis" with "carcinogens".

Page 5-5, 3rd paragraph, line 2: I would suggest deleting "excess".

Page 5-28, 3rd paragraph, line 5: "International Commission of Radiological Protection" is the name of the organization.

Page 5-31, 2nd paragraph, line 4: I would suggest replacing "very" with "acceptably".

Page 5-52, 4th paragraph, line 4: I would suggest deleting "very safe" since the term is ambiguous.

I hope that my comments will be helpful to you. If there is anything I can do to be of further assistance, please don't hesitate to call on me.

Sincerely,

Arthur C. Upton, M.D.
Professor and Chairman

ACU/lw

Velzy Associates

RECEIVED AUG 14 1984

August 13, 1984

Charles R Velzy Associates, Inc.
Consulting Engineers
355 Main Street
Armonk, New York 10504
Telephone: 914/273-9840

Dr. David Lipsky, Group Manager
Public Health and Chemistry
Fred C. Hart Associates, Inc.
530 Fifth Avenue
New York, New York 10036

Dear Dr. Lipsky:

Enclosed please find my comments on the draft report on health risks from PCDD/PCDF emissions from the Brooklyn Navy Yard proposed RR facility.

I have also enclosed copies of the following pages from the draft report on which I have noted typos, unclear or incomplete sentences, and/or have indicated recommended wording changes or additions to improve accuracy or preciseness of expression:

Pages 12 and 13 in the Executive Summary
Pages 1-6, 1-9, 2-38, 3-15, 3-16, 3-33, 5-24 and 5-41 in the main body of the report
Pages B-1, B-2 and B-4 in Appendix B.

I turst you will find these suggestions helpful. Thank you for the opportunity to participate in this project. Would you please send me a copy of the final, complete report. Thank you.

Very truly yours,

Charles O. Velzy, P.E.
President

COV/maf
encl.

COMMENTS ON
DRAFT REPORT ON "ASSESSMENT OF POTENTIAL PUBLIC HEALTH IMPACTS ASSOCIATED WITH PREDICTED EMISSIONS OF PCDD/PCDF FROM THE BROOKLYN NAVY YARD RR FACILITY"

I agree with the overall conclusion of this Report that a modern, carefully designed and operated energy from solid waste plant does not represent a significant risk to public health by reason of potential discharges of PCDD/PCDF. This confirms earlier study conclusions reached by ASME and EPA. However, I have problems with some of the detailed explanations offered for equipment selection and predicting performance.

Thus, on pages 2-8, 3-23, 3-24, and 3-31 (at least), it is indicated that PCDD/PCDF tend to concentrate on small particles since small particles have a greater surface area than larger particles for the same given mass. On pg. 3-24, it is pointed out that Karasek has generated some data which is contrary to this theory. However, it is indicated that this is the only contrary data and it is dismissed as being anomalous.

I think this conclusion is drawn too hastily and may not be correct. Karasek is not the only investigator to find PCDD/PCDF concentrations higher on larger particles. Tiernan, et al, in an article published in 1982, cited in your references for Chapter 3, shows TCDD concentrations 2 to 3 times greater on 10μm to 3μm particles than on 1μm and smaller particles. More recent, as yet unpublished, test results seem to confirm these results. A possible explanation for these results may be contained in the comments referenced to Barnes, 1983, in the first complete paragraph on page 2-11 of your Report.

The implication of this, in my judgment, is that a bag house may not have a significant advantage over a high efficiency electrostatic precipitator from the standpoint of control of PCDD/PCDF emissions. More important considerations, when striving for maximum control of emissions of these compounds, is the split between particulate sorbed material versus that in gaseous or vapor form at stack conditions, and conditions (most important perhaps, temperatures) that result in adsorption and desorption of these compounds on particulates at stack conditions. As correctly noted in the Report, we have literally no definitive information with which to make predictions in these two areas.

In summary on this point, I agree with the decision to use a bag house on the Brooklyn Navy Yard plant in order to maximize smaller particulate removal through filtration of stack gases. However, the numerical projections of removal of PCDD/PCDF may be inaccurate due to uncertainties as to the form of these compounds at stack conditions. In any case, there does not seem to be a significant health risk.

In the last paragraph on page 3-11, the Report apparently attempts to describe a sampling methodology that was generally in use prior to promulgation of EPA Method 5. These earlier methods frequently obtained a sample of particulates by drawing a sample of flue or stack gases out of the duct and filtering the sample immediately at stack temperature using an in-stack filter. Current European methodology for particulate sampling closely parallels these methods.

However, I do not believe the conclusion drawn at the end of the paragraph can be supported. Tiernan has not collected, in any manner whatsoever, the samples that he has analyzed in his laboratory. Further, none of the general references that I have reviewed in this field give any indication as to the sampling method that was used in the investigation. EPA test reports do describe sampling methodology which is as described at the top of page 3-12, Modified EPA Method 5. This absence of definitive information on sampling methodology used in these investigations, or absence of general prior agreement on a single standard method of test, is a problem in the field today.

Similarly, the last two sentences on page 3-12 of the Report represent a tremendous understatement. Combustion conditions during testing for PCDD/PCDF are usually not described at all, or are completely and/or inaccurately characterized. Only this year, 1984, have we begun to see some work to relate combustion conditions to trace organic emissions. This information should allow us to refine our estimates of emissions and achieve more cost effective control in the future.

I believe the statement in the second line of the first paragraph on page 3-13 is not accurate. Benfenati, et al, were unable to show any correlation between combustion conditions and PCDD/PCDF emissions, except for a general loose correlation between minimum combustion temperature and PCDD/PCDF emissions. The last sentence in this same paragraph would be more accurate if it read as follows: "Slow operator response to temperature excursions and poor control of the air/fuel mixture may potentially result in significant increases in PCDF and PCDD emissions."

Finally, I believe the use of the particle size data from the tests on the Braintree Incinerator to predict size distribution for particulate emissions from modern electrostatic precipitators is flawed. The Braintree plant, when designed many years ago, incorporated a precipitator with a particulate removal efficiency of about 90%. During the tests that produced the particle size distribution data cited, the precipitator was reportedly only operating at approximately 74% efficiency. When operating at such a low removal efficiency, the emissions must include a much larger fraction of large sized particles than would be found in a unit considered for a facility such as the Brooklyn Navy Yard plant. Precipitators at such a plant would have a removal efficiency in excess of 99%. Such a unit should essentially totally remove material larger than 2μm in size.

Again, the above comments are offered from the standpoint of improving the accuracy of the Draft Report in certain specific areas. I don't feel that any of these points change the basic conclusion of the Report that a modern, carefully designed and operated energy from solid waste plant does not represent a significant risk to public health by reason of potential discharges of PCDD/PCDF.

C.4 Risk Assessment

A risk assessment was performed to estimate the risks associated with predicted maximum PCDD and PCDF concentrations in ambient air, soil, dust and dirt downwind of the BNYRRF. The assessment compared the predicted ambient air concentrations and estimated daily intake levels for PCDDs and PCDFs with: (1) applicable standards and criteria; and (2) concentrations of PCDDs and PCDFs known or suspected to cause a toxic effect.

In reviewing the findings of our risk assessment it is important to keep in mind the methodological limitations of the risk assessment process.

First, a risk assessment, while based upon scientific considerations, often requires the application of sound technical and scientific judgement or assumptions. The use of assumptions rather than scientific experimental fate, transport, and bioavailability of contaminants such as PCDDs and PCDFs.

M! left! some

Second, a risk assessment frequently requires extrapolation from high-dose animal feeding studies to estimate risk to humans at the extremely low dosages or concentrations of contaminants found in the environment. Data are not available to determine the actual shape of a dose/response curve (i.e., the level of risk), or the best method to extrapolate risk. Accordingly, there is a great range of uncertainty regarding actual risk (at very small concentrations) for a given contaminant.

In the absence of sufficient data or knowledge about the degree of exposure, intake, and bioavailability of contaminants, the typical risk assessment uses the most reasonable assumptions possible. Typically, "worst-case" scenarios or conservative assumptions are used in the assessment process. A conservative assumption is one which increases the likelihood that a substance will represent a hazard to public health.

However, the use of a number of "worst-case" or conservative assumptions carries the danger that the estimate of risk can become vastly overstated and therefore unrealistic. Risk assessments relying upon "worst-case" scenarios must be evaluated critically regarding the degree of realism in the model used to estimate risk.

Several conservative assumptions were incorporated into our assessment. They include the following:

- Use of worst-case assumptions for three potential pathways of exposure: inhalation of gaseous or particulate emissions, and ingestion or dermal absorption of particulates deposited on outdoor and indoor surfaces. Typically, risk assessments of point-source emissions assess risks only for the inhalation pathway.

- Application of a toxic equivalency multiplier equal to 59. This number provides an estimate of the non-carcinogenic toxicity of the complex mixture of PCDDs and PCDFs compared with the concentration of 2,3,7,8-TCDD. This equivalency factor was also used to estimate carcinogenic equivalency as a worst-case assumption although such an application is speculative.

see 2-6 [illegible]

In the absence of sufficient data or knowledge about such issues as the degree of exposure, intake, fate and bioavailability of contaminants, the typical risk assessment uses the most reasonable assumptions possible, erring on the side of public health. Typically, "worst-case" scenarios or conservative assumptions are used in the assessment process to provide an added safety factor. A conservative assumption is one which increases the likelihood that a substance represents a hazard to public health.

To provide an element of conservatism, the following safety factors were incorporated into our risk assessment:

- Risks were calculated based on maximum 24 hours a day exposure, over a 70 year lifetime at the point of maximum impact.
- Assessment of three potential pathways of exposure: Inhalation of gaseous or particulate emissions, and ingestion or dermal absorption of particulates deposited on outdoor and indoor surfaces.
- Application of a toxic equivalency multiplier equal to 61. This number provides an estimate of the non-carcinogenic toxicity of the complex mixture of PCDDs and PCDFs compared with the concentration of 2,3,7,8-TCDD. This equivalency factor was also used to estimate carcinogenic equivalency as a worst-case assumption although such an application is speculative.

1 ?
see [illegible]
13

- No losses of PCDDs were assumed through volatilization or degradation or losses from such actions as rainfall.
- Indoor ambient air quality was assumed to equal outdoor air quality.
- The most conservative cancer risk extrapolation model was included to estimate an upper bound limit to increased cancer risk.
- Conservative assumptions for bioavailability, and rates of ingestions and dermal contact were included to estimate worst-case daily intakes of PCDDs.

However, the use of a number of "worst-case" or conservative assumptions carries the danger that the estimate or risk can become vastly overstated and therefore unrealistic. Risk assessments relying upon "worst-case" scenarios must be critically evaluated with regard to the degree of realism in the model used to estimate risk.

Arthur Upton, M.D.--Professor and Chairman, Department of Environmental Medicine, New York University School of Medicine. Former Director, National Cancer Institute.

Charles Velz~~k~~y, P.E.--President, Charles R Velz~~k~~y ~~and~~ Associates, Inc. Extensive experience in design and operation of solid waste incineration facilities and air pollution control technologies.

The panel met to review and comment on the proposed scope and approach of this report on February 28, and reconvened on April 29 to review the first draft. The written comments of the panelists on the final version of this report appear as Appendix D.

specific dioxin cogeners. However, although TCDD is an extremely potent enzyme inducer in cell cultures, there is no demonstrated correlation between enzyme induction and cytotoxicity. This observation implies that despite the observed correlation in animal models, there may be no direct connection between enzyme induction and the degree of toxicity of 2,3,7,8-TCDD.

Vitamin A Depletion. Many of the toxic effects of 2,3,7,8-TCDD resemble the effects of Vitamin A (retinol) deficiency. These include epithelial lesions, keratosis and immunosuppressive effects. It has been demonstrated that the administration of a single oral dose of 2,3,7,8-TCDD produces a dose-related increase in the hepatic (liver) storage of Vitamin A in rats (Thunberg et al. 1979, 1980). These results suggest that an induced Vitamin A deficiency may be responsible for some of the toxic effects produced by 2,3,7,8-TCDD.

Lipid Peroxidation. Sweeney and Jones (1983) have suggested increased lipid peroxidation as a possible mechanism of 2,3,7,8-TCDD toxicity. Based on limited data, it appears that iron deficiency inhibits in vitro lipid peroxidation and reduces the hepatotoxic effects of 2,3,7,8-TCDD. Also lipofuscin pigments, by-products of lipid peroxidation, are increased in the heart muscle of rats treated with 2,3,7,8-TCDD. Thirdly, administration of an antioxidant to mice provided some protection from porphyria induced by 2,3,7,8-TCDD. More recent studies (Stohs et al., 1983) indicate that 2,3,7,8-TCDD may accelerate lipid peroxidation in Sprague-Dawley rats.

2.4.8 Summary. Relatively little is known regarding the effects of PCDDs and PCDFs on humans. Animal studies, which are limited primarily to 2,3,7,8-TCDD, indicate that this compound shows considerable variation in toxicity and varying effects among species, as well as a delay between the administration of this material and the manifestation of a toxic effect.

As regards humans, most information is derived from cases of accidental exposure to mixtures containing PCDDs. Assessing the effects of these uncontrolled exposures and relating effects solely to exposure to PCDDs is difficult. The symptoms observed in these incidents include skin conditions; hair loss and excess hair growth; nervous disorders; respiratory during testing by the USEPA. The owners of the Hampton plant have been requested by USEPA to revise their operating conditions in order to reduce the PCDF and PCDD emissions, and the facility is due to be re-tested. Clearly, the emissions from this incinerator are not representative of normal emissions under generally acceptable operating conditions. ~~operations.~~ However, this facility was sampled for both particulate and gaseous forms of PCDFs and PCDDs, and the data reflects total emissions. The two plants in Milan, Italy, are resource recovery steam plants with Volund combustion systems. The Eskjo, Sweden, plant is a refuse-fired fluidized-bed boiler operating at 700°C and two seconds gas retention time. Both gaseous and condensible forms of PCDFs and PCDDs were measured at these Italian plants and at the Sweden plant. The Zaanstad, Netherlands plant is a simple refractory-lined furnace. The effluent was sampled and analyzed for solid PCDD and PCDF forms only. Of these systems the Chicago Northwest facility and the Zurich-Josefstrasse facility are the closest in design and operation to the BNYRRF. In addition, these facilities were sampled using methodology which includes gaseous and solid forms of PCDFs and PCDDs. Of note, the emissions from these facilities are among the lowest of all those tested. The highest values were obtained from incinerators about which absolutely no information was presented regarding furnace combustion conditions during testing.

3.4 Rates of Dioxin Emission from Incinerators

From Section 3.2 it is clear that a complex set of circumstances influence the rate of PCDF and PCDD materials in incinerator effluents. The results of the laboratory studies indicate that the primary method of achieving minimum emissions is a maximization of combustion efficiency. That is, with combustion temperatures of about 900°C, the air/fuel mixture must be just slightly oxygen-rich, the mixture must be homogeneous (no stratification), and the gas residence time at the average combustion temperature must be at least one second. These conditions are not extreme; they are attainable with fully developed and tested technology. This is demonstrated by the emission data obtained from the Chicago Northwest facility (Redford et al., 1981) and the Zurich-Josefstrasse facility (SFOEP, 1982).

The system central to these facilities, the Martin stoker-grate, has been developed over many years with the goal of promoting optimum ~~effective resource recovery. That is, these systems were designed to obtain the highest energy output, and therefore the "optimization of~~ combustion efficiency. ~~was the goal of the design.~~

In contrast, many other incinerators were designed with the primary goal of reducing waste volume. It is cheaper and easier to design and build an incinerator that effectively reduces waste volume without providing a high combustion efficiency. These facilities do not have the high-velocity secondary air nozzles to provide air/fuel mixing, or the larger dimensions to provide long gas residence times, or the sophisticated control systems necessary to keep conditions from exceeding their desired ranges. Two relatively simple incinerators without resource recovery are the Como, Italy and the Zaanstad, Netherlands facility. Emissions from these plants are one to two orders of magnitude greater than the Chicago, Northwest facility.

However, a resource recovery design in itself does not assure that PCDF and PCDD emissions will be minimal. Three systems that were designed for resource recovery emitted relatively high PCDF and PCDD emissions. These are the two plants in Milan, Italy (Cavallaro et al. 1980) with Volund steam generation systems and the Hampton, Virginia refuse-fired steam boiler (Tiernan et al. 1983). Emissions from these systems are two to three orders of magnitude higher than the Chicago, Northwest facility emissions. Six Italian plants were tested but the types of incinerators were not described These ranged several orders of magnitude from moderate to very high levels (Cavallaro et al. 1982). unclear ?

The extreme range of emissions shown in these studies demonstrates that the factors influencing PCDF and PCDD emissions are complex. Although design can play a significant role in the magnitude of emissions, it is not probable that design alone can assure low emissions. The most probable cause of the wide range of emissions is flucuations in operating conditions from plant to plant and from day to day. This shows that the most important

3.8 Summary

In summary, PCDF and PCDD emissions in incinerator effluents can originate from a number of sources and/or chemical reactions, such as being a part of raw refuse, being formed from precursors, and being formed from degradation products of materials commonly found in solid waste.

Whatever the cause of formation or occurrence, the combustion conditions necessary for destruction include a minimum of one to two seconds of gas residence time at a minimum combustion temperature of 900-1,000°C, very turbulent conditions in the high-temperature zone, and an air/fuel mixture with a slight excess of oxygen.

The incinerator design selected for the BNYRRF appears to fulfill the requirements for efficient combustion and maximum destruction of PCDFs and PCDDs. Furthermore, the use of auxiliary burners will assure that the minimum combustion temperature is consistently maintained. In addition, a more efficient fly ash pollution control device than is generally used on incinerators has been selected. Since at least some of the PCDF and PCDD materials will be adsorbed on particulate, less of these materials will be emitted and the exposure to the public will be less than if the less efficient electrostatic precipitator had been selected. However, the exact portion of PCDFs and PCDDs in the environment which can be attributed to any single source or process is impossible to determine.

Emission test data from a number of incinerators has demonstrated a wide range of PCDF and PCDD emissions spanning several orders of magnitude. High levels of emissions have been observed from several types of incinerators, indicating that operational factors have as much or more effect on PCDF and PCDD emissions than incinerator design. However, the lowest emissions were observed from incinerators with the same basic design as the BNYRRF. This is an encouraging point and may mean that effective operation and maintenance is easier on these units. The BNYRRF has also been designed with additional control features not found on the incinerators tested with even the lowest emissions.

~~Margin text 0,~~

The predicted maximum average annual concentration of 2,3,7,8-TCDD at ground and elevated receptors of 0.00168 pg/m^3 equals 0.014% of the Netherlands standard. Using a toxic equivalency factor of 59, the levels of TCDD toxic equivalents are still only 0.83% of the Netherlands ADI.

5.4.3 <u>Comparison with NYSDEC Guideline</u>. NYSDEC used the EPA's Risk Assessment of the Municipal Waste Combustors (MWCs) to establish a performance guideline for evaluating other combustion sources. As described in Section 5.3.1, EPA found a maximum annual average ambient air concentration at ground level equal to 9.2×10^{-14} g/m^3 for all T_4CDDs. EPA performed a risk assessment based on these concentrations and stated that the excess cancer risks (which ranged up to 19×10^{-6}) presented no significant risk to the public. On the basis of EPA's risk assessment, the maximum PCDD level found was then adopted by NYSDEC as a guidance level. Using data from Table 4-1, the maximum average TCDD concentrations predicted in the ambient air downwind of the BNYRRF at ground level and elevated receptors is 0.026 pg/m^3 which is equal to 28.2% of the NYSDEC guideline for total TCDDs.

5.4.4 <u>NYSDOH Guideline</u>. NYSDOH established air and exposure guidelines for reentry into a Binghamton, New York, office building that had been evacuated following an electrical transformer fire. For workers exposed for 250 days/year, 8 hour/day, the TCDD toxic equivalent concentration should not exceed 15 pg/m^3. This concentration adjusted for 24 hour/day exposure for 365 days per year equals 3.4 pg/m^3. Based upon our air dispersion model (Table 4-1) we predict an average annual 2,3,7,8-TCDD ambient air concentration at ground level equal to .00168 pg/m^3 which is equal to a total TCDD toxic equivalent concentration of .099 pg/m^3. Therefore, the predicted emissions from the BNYRRF are expected to result in an annual average ambient air concentration of 2,3,7,8-TCDD and TCDD toxic equivalents that is only 0.049% and 2.9% of the NYSDOH guideline, respectively.

5.5 Computation of a "Worst-Case" Upper Bound to the Level of Risk Associated with Emissions from the BNYRRF.

In the previous section, the maximum annual average PCDD and PCDF concentrations at ground level and elevated receptors were compared to the

As discussed in Chapter 4.0, PCDD levels in home dust and street dirt on a surface area basis were also used to estimate risk. The maximum accumulation on floors was estimated assuming indoor deposition at 25% of the outdoor rate, with a 30-day period of accumulation.

There is some evidence to suggest that a 30-day accumulation period is overly conservative. The data provided by Solomon et al.; if extrapolated, indicates that there is from 0.6 to 1g dust/m^2 in single family urban middle class homes (gas heated) in Champagne-Urbana Illinois. His data, if applied to the PCDD and total particulate deposition rates, would indicate that steady state conditions for dust buildup in homes would be reached in three to five days (Solomon, 1977).

For outdoor deposition the accumulation period in ~~an~~ urban streets is unknown. The Swiss EPA in their assessment of dioxin emissions from incinerators, used an estimated half life equal to 14 days for rural environments (SFOEP, 1982). Consistent with this Swiss EPA assessment, we have assumed a 30 day period of accumulation as a reasonable accumulation period.

The estimated daily intake through the ingestion pathway calculated on a weight or surface area basis is presented in Tables 5-10 and 5-11.

The maximum estimated daily intake calculated by either method provides reasonably similar results. On a weight basis, the maximum estimated daily intake of 2,3,7,8-TCDD ranged from 2.5×10^{-16}g/day to 2.9×10^{-14}g/day. On a surface area basis, the daily intake ranged from 1.3×10^{-16} to 6.8×10^{-15}g/day.

5.5.4.3 Daily Intake From Dermal Adsorption. Estimating a daily intake due to dermal absorption requires a determination of the surface area or exposed skin, the frequency of contact between the exposed skin and contaminated surfaces, and the rates of absorption for PCDDs and PCDFs bound tightly to soil, dust, and fly ash. Information to calculate these data are also not well documented. Accordingly, a number of assumptions were used to provide a range and upper bound estimate for daily intake through the dermal pathway.

APPENDIX B -- CALCULATIONS

BROOKLYN NAVY YARD AND RESOURCE RECOVERY FACLITY

PREDICTED PCDD AND PCDF EMISSIONS AND ASSOCIATED ENVIRONMENTAL IMPACTS

PCDD and PCDF Concentrations in Flue Gas

Concentrations in BNYRRF flue gas were based upon tests of Chicago Northwest and Zurich-Josefstrasse facilities. Corrections were made for flue gas conditions projected for BNYRFF. The concentrations presented here assume: (1) gas phase PCDD and PCDF emission, or (2) particulate emission with electrostatic precipitators used for particulate control. Calculations in the following sections account for particulate emission of PCDD and PCDF with fabric filter particulate control.

	BNYRRF	Chicago Northwest	Zurich-Josefstrasse
CO_2 % (dry)	10.5	9.5	9.3
H_2O %	13.63	13.1	14.7
Dry Gas Fraction	.8637	.869	.853
Standardized Temp.	0°C (N)	20°C (S)	0°C (N)

? see following pg.

Chicago, N.W. data (CNW)

$$(\text{ng/Nm}^3)\ \text{BNY} = (\text{ng/dry Sm}^3)\ \text{CNW} \times (\%\ CO_2)\ \text{BNY}/(\%\ CO_2)\ \text{CNW} \times (\text{dry gas fraction})\ \text{BNY} \times (\text{abs. temp-S})/(\text{abs. temp-N})$$

Example, Tri-CDF

$$300 \text{ ng/dSm}^3 \times 10.5/9.5 \times .8637 \times 293/273$$

$$= 307.4 \text{ ng/Nm}^3$$

Zurich-Josefstrasse data (Z-J)

$$(\text{ng/Nm}^3) \text{ BNY} = (\text{ng/Nm}^3) \text{ Z-J} \times (\% \text{ CO}_2) \text{ BNY}/ (\% \text{ CO}_2)\text{Z-J}$$
$$\times \text{ (dry gas fraction) BNY/(dry gas fraction)Z-J}$$

Example, Penta-CDF

$$27.3 \text{ ng/Nm}^3 \times 10.5/\boxed{10.9} \times .8637/.853$$
$$= 26.6 \text{ ng/Nm}^3$$

?

see previous pg

TABLE B-1

PREDICTED BNYRRF EMISSION RATES IF ELECTROSTATIC PRECIPITATORS WERE USED, OR IF ALL PCDD AND PCDF EMISSIONS WERE GASEOUS

	Reported Concentration	BNYRRF Concentration(3)	BNYRRF Mass Emission Rate (4)
Tri-CDF	300(1)	307.4	51.18
Tetra-CDF	90(1)	92.2	15.35
Penta-CDF	27.3(2)	26.6	4.43
Hexa-CDF	7.5(1)	7.7	1.28
Hepta-CDF	62(1)	63.5	10.58
Octa-CDF	0.60(1)	0.6	0.10
TOTAL-CDF	--	498.0	82.92
Tri-CDD	13(1)	13.3	2.22
Tetra-CDD	6.3(1)	6.5	1.07
Penta-CDD	11.0(2)	10.7	1.79
Hexa-CDD	7.6(1)	7.8	1.30
Hepta-CDD	16(1)	16.4	2.73
Octa-CDD	2.5(1)	2.6	0.43
TOTAL-CDD	--	57.3	9.54
2,3,7,8-TCDD	0.41	0.42	0.07

? see pgs B1+B2

(1) Chicago Northwest, ng/dSm^3 at 20°C and 9.5% CO_2

(2) Zurich-Josefstrasse, ng/Nm^3 at 0°C, 10.9% CO_2 (dry) and 14.7% H_2O

(3) ng/Nm^3 at 0°C, 10.5% CO_2 (dry), and 13.63% H_2O

(4) ug/sec

APPENDIX E

Curriculum Vitaes of Peer Review Panel Members

Curriculum Vitae

Thomas C. Chalmers, M.D.

Born Forrest Hills, New York
December 8, 1917

S.S. # 041-18-1186

Business Address
Mount Sinai Medical Center
One Gustave L. Levy Place
New York, New York 10029
(212) 650-8254

Education & Training

Yale College	1936-39
Columbia College of Physicians and Surgeons	M.D. 1943
Medical Intern, Presbyterian Hospital, New York City	1943-44
Research Fellow, Department of Medicine, New York University Malaria Research Unit, Goldwater Memorial Hospital, NYC	1944-45
Assistant Resident & Resident, 2nd and 4th Medical Services (Harvard), Boston City Hospital, Boston	1945-47
Research Fellow, Harvard Medical School and Thorndike Memorial Laboratory, Boston City Hospital, Boston	1946-47

Licensure

Licensed to practice medicine
New York State License No. 42374 Date Issued: May 12, 1944

Academic Appointments

1947-1961	Harvard Medical School	Assistant in Medicine Instructor Clinical Associate Assistant Clinical Professor of Medicine
1961-1968	Tufts University School of Medicine	Professor of Medicine
1962-1975	Harvard Medical School	Lecturer in Medicine
1970-1973	George Washington University School of Medicine	Professor of Medicine
1973-1983	Mount Sinai School of Medicine of the City University of N.Y.	Dean and President Professor of Medicine
1983-	Mount Sinai School of Medicine of the City University of N.Y.	President Emeritus, Dean Emeritus and Distinguished Service Professor

HOSPITAL AND RELATED APPOINTMENTS

Boston City Hospital, 2nd and 4th Medical Services, (Harvard) and Thorndike Memorial Laboratory, Boston

1947-1948	Out-patient Physician
1949-1953	Assistant Visiting Physician
1955-1968	Associate Visiting Physician

Mount Auburn Hospital, Cambridge

1947-1953	Junior Physician
1955-1968	Associate Visiting Physician

New England Center Hospital, Boston

1961-1968	Associate Staff

Faulkner Hospital, Boston

1955-1968	Consultant in Medicine

Lemuel Shattuck Hospital, Boston

1955-1968	Chief of Medical Services

Director of Hepatitis Study, Commission in Liver Disease, Armed Forces

1951-1953	Epidemiological Board

Veteran's Administration Central Office, Washington, D.C.

1968-1970	Assistant Chief Medical Director for Research and Education

National Institute of Health

1970-1973	Associate Director for Clinical Care & Director of the Clinical Center

Mount Sinai Medical Center, New York City

1973-1983	President

MILITARY SERVICE - United States Army Reserve, Walter Reed Army Hospital Washington, D.C.

1953-1955	Captain

COMMITTEES AND BOARDS

Federal Advisory Committees

National Heart and Lung Institute

1961-1965	Training Committee
1964-1969	Heart Special Projects Committee (Chairman, 1968-69)
1968	Diet-Heart Review Panel

National Cancer Institute

1965-1966	Cancer Chemotherapy Collaborative Program Review Committee (Richardson Committee)

Health Resources Administration (HEW)

1974-	National Center for Health Statistics (Consultant)

Food and Drug Administration

1970-1974	Consultant to the Bureau of Drugs
1973-1975	Drug Experience Advisory Committee
1975-1976	Review Panel on New Drug Regulations (Chairman)

Veterans Administration

1971-1974	Cooperative Studies Evaluation Committee (Chairman, 1972-74)
1974-1975	Medical School Assistance Review Committee
1976-	Center for Ulcer Research and Education, Los Angeles Advisory Board Member

Department of Defense

1965-1973	Surgeon General's Advisory Committee on General Medicine, Subcommittee on the Liver
1970-1972	United States Army Medical Research and Development Command, Consultant to the Commander

Clinical Trial Policy Advisory Boards and Data Monitoring Committees

1966-1975	National Heart and Lung Insitute, Coronary Drug Project
	1966-1968 Special Review Panel
	1966-1975 Data and Safety Monitoring Committee
1971-	National Heart and Lung Institute, Safety Monitoring Committee, Type II Hyperlipidemia Coronary Intervention Study
1968-1972	National Heart and Lung Institute, Urokinase-Streptokinase Pulmonary Embolism Trials Policy Board
1971-1973	Boston Collaborative Drug Surveillance Program, Myocardial Infarction Study Advisory Board
1971-1978	National Institute of Arthritis, Metabolism and Digestive Diseases, National Cooperative Crohn's Disease Study Advisory Board (Chairman)
1972-1975	National Heart and Lung Institute, Hyper-immune Gamma Globulin Trials Policy Board
1972-1977	University Group Diabetes Program, Policy Advisory Board (Chairman)
1978-	National Institute of Arthritis, Metabolism and Digestive Diseases, Member of Policy Advisory Committee of the National Cooperative Gallstone Study
1974-	Persantine-Aspirin Re-Infarction Study Policy Board (Chairman)
1975-	Program on the Surgical Control of the Hyperlipidemias, Data Monitoring Committee (Chairman-1978)
1976-	VA-NHLBI Cooperative Study of Mild Hypertension, Advisory Committee on Trial Design

National Academy of Sciences - National Research Council Committees

1965-1969	Committee on Epidemiology and Veterans Follow-up Studies
1974-1977	" " " " " " "
1970-1972	Ad hoc Committee on Hepatitis-Associated Antigen Tests Ad hoc Committee on Hepatitis-Associated Antigen Carrier Guidelines
1972-1973	Division of Medical Sciences, Member-at-large
1974	Visiting Committee, Drug Review Board

MISCELLANEOUS COMMITTEES AND BOARDS

1963-1967	American Gastroenterological Association, Committee on Research
1964-1967	American Public Health Association, Committee on New Drugs
1966-1970	Pharmaceutical Manufacturers Association Foundation Advisory Committee to the Faculty Development Awards in Clinical Pharmacology Program (Chairman, 1968-1970)
1966-1968	Pharmaceutical Manufacturers Association Foundation Scientific Advisory Committee
1970-1976	American Board of Internal Medicine, Subspeciality Board on Gastroenterology
1974-1976	American Gastroenterological Association, Committee on Publications and Communications
1974-	National Disease and Therapeutic Index, Advisory Committee of Physicians and Educators
1975-	Board of Overseers of Harvard College, Visiting Committee on Statistics
1975-	The Public Health Research Institute of the City of New York, Inc., Board of Directors
1977-1979	National Commission on Digestive Diseases, Chairman of the Subcommittee on Clinical Trials
1978-1982	Institute of Medicine (Natl. Acad. of Sci.) Membership Committee
1978-1979	Advisory Panel on Coronary Disease (Council on Sci. Affairs of the AMA)
1981-	International Physicians for the Prevention of Nuclear War
1982-	Physicians for Social Responsibility
1982-	Technical Board of the Milbank Memorial Fund
1983-	Chairman, of Trustees, Dartmouth-Hitcock Med. Center

PROFESSIONAL MEMBERSHIPS

American Association for the Study of Liver Disease (President, 1959)
American Board of Internal Medicine, 1950 and Recertification, 1974
American Clinical and Climatological Association
American College of Gastroenterology (Honorary Fellow, 1975)
American College of Physicians
American Federation for Clinical Research
American Public Health Association
American Society for Clinical Investigation
Associated Medical Schools of New York (Vice President, 1974-1975; President, 1976-1977)
Association of American Medical Colleges
Association of American Physicians
Biometric Society
International Association for the Study of the Liver (Councilor for North America, 1970-1974)
Medical Society of the County of New York
Medical Society of the State of New York
National Academy of Science, Institute of Medicine
New York Academy of Medicine (Fellow)

PROFESSIONAL MEMBERSHIPS (cont'd.)

Practitioners Society of New York
Society for Epidemiological Research
Society for Experimental Biology and Medicine
National Library of Medicine, Board of Regents (1978-1979)
AOA (1979)
Ethics Advisory Board-Special Consultant, 1980 (NIH) Department of Health and Human Services

AWARDS

Julius Friedenwald Medal for Outstanding Achievement in Gastroenterology 1982
Paul Lazarfeld Award for Research 1982 given by the Evaluation Research Society

PRINCIPAL INVESTIGATOR/PROGRAM DIRECTOR:

BIOGRAPHICAL SKETCH

Give the following information for key professional personnel listed on page 2, beginning with the Principal Investigator/Program Director. Photocopy this page for each person.

NAME	TITLE	BIRTHDATE *(Mo., Day, Yr.)*
Thomas C. Chalmers , M.D.		12/8/17

EDUCATION *(Begin with baccalaureate or other initial professional education and include postdoctoral training)*

INSTITUTION AND LOCATION	DEGREE *(circle highest degree)*	YEAR CONFERRED	FIELD OF STUDY
Yale College		1936-39	
Columbia College of Physicians & Surgeons	M.D.	1943	Medicine
Intern, Presbyterian Hospital, NYC		1943-44	Medicine
Resident, Boston City Hospital		1945-47	Medical
Harvard Medical Services			

RESEARCH AND/OR PROFESSIONAL EXPERIENCE: Concluding with present position, list in chronological order previous employment, experience, and honors. Include present membership on any Federal Government Public Advisory Committee. List, in chronological order, the titles and complete references to all publications during the past three years and to representative earlier publications pertinent to this application. DO NOT EXCEED TWO PAGES.

ACADEMIC APPOINTMENTS

1947-61	Harvard Medical School, Assistant Clinical Professor of Medicine
1961-68	Tufts university Medical School, Professor of Medicine
1962-75	Harvard Medical School, Lecturer in Medicine
1970-73	George Washington University School of Medicine, Professor of Medicine
1973-83	Mount Sinai School of Medicine of the City University of New York Dean and President
1983 -	Mount Sinai School of Medicine of the City University of New York, Professor
1983-84	Visiting Professor, Dept. Health Policy & Management, Harvard School of Public Health, Director, Clinical Trials Unit.

ADMINISTRATIVE POSTS

1955-68 Lemuel Shattuck Hospital, Chief of Medicine
1968-70 Assoc. Chief, Medical Director for Res. & Ed., Veterans Administration
1970-73 Assoc. Director for Clinical Research and Director, Clinical Center, NIH
1973-83 President, Mount Sinai Medical Center

CLINICAL TRIAL EXPERIENCE

Data and Safety Monitoring Committees
1966-75 NHLBI: Coronary Drug Project
1971-76 NHLBI: Type II Hyperlipidemia coronary intervention study
1975 Program on surgical control of hyperlipidemias (chairman)

POLICY ADVISORY BOARDS

1968-72 NHLBI: Urokinase-Streptokinase Pulmonary embolism trials
1971-73 Boston collaborative drug surveillance program - myocardial infarction study
1971-78 NIAMDD: National Cooperative Crohn's Disease Study (Chairman)
1972-75 NHLBI: Hyperimmune Gamma Globulin trials
1972-82 NIAMDD: University Group Diabetes Program (Chairman)
1978-82 NIAMDD: National Cooperative Gallstone Study
1974 Persantine Aspirin reinfarction studies (Chairman)

Presentation and Pertinent Publications

1. Chalmers, T.C., Eckhardt, R.D., Reynolds, W.E., Reifenstein, R.W., Deane, N., Smith, C.W., Cigarroa, J.G., and Davidson, C.S. The treatment of acute infections hepatitis. Controlled studies of the effects of diet, rest, and physical reconditioning on the acute course of disease and on the incidence of relapses and residual abnormalities. J Clin Invest 34:1163-1234, 1955.

2. Plough, I.C., Iber, F.L., Shipman, M.E., and Chalmers, T.C. The effects of supplementary calories on nitrogen storage at high intakes of protein in patients with chronic liver disease. Am J Clin Nutr 4:224-230, 1956.

3. Chalmers, T.C., Iber, F.L., and Uzman, L.L. Hepatolenticular (Wilson's Disease) as a form of idiopathic cirrhosis. N. Engl J Med 256; 235-242, 1957.

4. Iber, F.L. Rosen, H., Levenson, S.M. and Chalmers, T.C. The plasma amino acids in patients with liver failure. J Lab Clin Med 50:417-425, 1957.

5. Moore, E.W., Mitchell, M.L., and Chalmers, T.C. Variability in absorption of insulin I-131 in normal and diabetic subjects after subcutaneous and intramuscular injection. J Clin Invest 38:1222-1227, 1959.

6. Mashford, M.L., Mahon, W.A., and Chalmers, T.C. Studies of the cardiovascular system in the hypotension of liver failure. N Engl J Med 267:1071-1074, 1962.

7. Moore, E.W., Strohmeyer, G.W., and Chalmers, T.C. Distribution of ammonia across the blood-cerebrospinal fluid barrier in patients with hepatic failure. Am J Med 35:350-362, 1963.

8. Greenberg, M.S. Strohmeyer, G.W., Hine, G.J., Keene, W.R., Curtis, G. and Chalmers Studies in iron absorption III. Body radioactivity measurements of patients with liver disease. Gastroenterology 46:651-661, 1964.

9. Jick, H., and Chalmers. T.C. Drug combinations-uses, dangers and fallacies. Clin Pharmacol Ther 5:673-676, 1964.

10. Linscheer, W.G., Patterson, J.F., Moore, E.W., Clermong, R.J., Robins, S.J., and Chalmers, T.C. Medium and long chain fat absorption in patients with cirrhosis. J Clin Invest 45:1317-1325, 1966.

11. Vlahcevic, Z.R., Adham, N.F., Chalmers, T.C., Clermont, R.J., Moore, E.W., Jick, H., Curtis, G.W., and Morrison, R.S. Intravenous therapy of massive ascites in patients with cirrhosis: I. Short term comparison with diuretic treatment. Gastroenterology 53:211-219, 1967.

12. Resnick, R.H., Chalmers, T.C., Ishihara, A.M., Garceau, A.J., Callow, A.D., Schimmel, E.M., O'Hara, E.T., and the Boston Inter Hospital Liver Group. A controlled study of the prophylactic portacaval shunt. Ann Intern Med 70:675-688, 1969.

13. Epstein, M., Berk, D.P., Hollenberg, N.K., Adams, D.F., Chalmers, T.C., Abrams, H.L., and Merrill, J.P. Renal failure in the patient with cirrhosis. Am J Med 49:175-185.

14. Chalmers, T.C., Block, J.B., and Lee, S. Controlled studies in clinical cancer research. N Engl J Med 287:75-78, 1972.

15. Freiman, J.A., Chalmers, T.C., Smith, H. Jr., et al. The importance of beta, the type II error and sample size in the design and interpretation of the randomized control trial. Survey of 71 "Negative" trials. N Engl J Med 299:690-694, 1978.

16. Berk, Aviva Ancona and Chalmers, Thomas C. Cost and Efficacy of the Substitutio of Ambulatory for Inpatient Care. Special Article, NEJM 304:383-397, 2/12/81.
17. Chalmers, Thomas C., Smith Harry, Jr., Blackburn, Bradley et al. A Method for Assessing the Quality of a Randomized Control Trial. 2(1) 31-49, 1981.
18. Baum, Mark L., Anish, David S., Chalmers, T.C. et al. A Survey of Clinical Trials of Antibiotic Prophylaxis in Colon Surgery: Evidence Against Further Use of No-Treatment Controls. NEJM 305: 795-799, 1981.
19. Sacks, H., Chalmers, T.C. and Smith, H. Jr. Randomized versus Historical Controls for Clinical Trials. AJM: Vol. 72, Feb. 1982 p. 233-240.
20. Chalmers, T.C., Celano, P, Sacks, H.S., Smith, H. Jr. Bias in Treatment Assignment in Controlled Clinical Trials. NEJM 309: 1358-1361, 1983.

DOUGLAS MICHAEL COSTLE

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Born: Long Beach, California July 27, 1939

EDUCATION:	Harvard University, Cambridge, Massachusetts, B.A.
	University of Chicago Law School, Chicago, Illinois, J.D.
PROFESSIONAL:	Counsel to the Law Firm of Wald, Harkrader & Ross, Washington, D.C.
	Counsel to the Law Firm of Updike, Kelly & Spellacy, P.C., Hartford, Connecticut
	Adjunct Lecturer, John F. Kennedy School of Government, Harvard University, Cambridge, Massachusetts
BOARDS:	Member, Board of Directors and Chairman of the Executive Committee of the Environmental Testing and Certification Corporation, Edison, New Jersey
February 1981 - August 1981	Visiting Scholar, Harvard School of Public Health, Cambridge, Massachusetts
1977 - 1981	Administrator, United States Environmental Protection Agency, Washington, D.C.
	Chairman, United States Regulatory Council (1978-1981)
	Chairman, United States Radiation Policy Council (1980-1981)

	President's Representative to NATO's Committee on the Challenges of Modern Society (CCMS)
	United States Chairman of the US-USSR Joint Committee on Cooperation in the Field of Environmental Protection
	United States Co-Chairman of the United States/Peoples Republic of China, Environmental Protection Protocol (1980-1981)
1975 - 1976	Assistant Director, Natural Resources and Commerce Division, Congressional Budget Office, Washington, D.C.
1973 - 1975	Commissioner, Department of Environmental Protection, State of Connecticut
1972 - 1973	Deputy Commissioner, Department of Environmental Protection, State of Connecticut
1971	Fellow, Woodrow Wilson International Center for Scholars, Smithsonian Institution, Washington, D.C.
1969 - 1970	Senior Staff Associate, Environmental and Natural Resources, President's Advisory Council on Executive Organization, Washington, D.C.
1968 - 1969	Senior Associate, Marshall Kaplan, Gans and Kahn, San Francisco, California (Urban policy planning firm)
1967	Associate, Kelso, Cotton, Seligman and Ray, San Francisco, California
1965 - 1967	Attorney, Economic Development Administration, U.S. Department of Commerce, Washington, D.C.
1964 - 1965	Trial Attorney, Civil Rights Division, U.S. Department of Justice, Washington, D. C.
PROFESSIONAL AFFILIATIONS:	Member of Bars of State of California and the District of Columbia

Precis of Curriculum Vitae

Theodore D. Goldfarb
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So. Setauket, New York 11720

(516) 736-2625 (home)
(516) 246-5053 (office)

Education: Ph.D.: University of California, Berkeley, 1959. (Phys. Chemistry)
A.B.: Cornell University, 1956 (With honors in chemistry)

Awards: State University of New York Chancellor's Award for Excellence in Teaching 1979

Texaco Fellowship in Chemistry 1958, 1959

Honorary Societies: Phi Beta Kappa, Sigma Xi.

Employment: Associate Professor of Chemistry, State University of New York at Stony Brook, 1967-present. Assistant Professor, 1959-1967. Consultant to Energy Systems Research Group, (a nonprofit research and consulting firm)on energy demand and environmental effects of various energy producing technologies. Legal consultant on chemical and fire safety hazards and product liability. Visiting Professor, Center for the Biology of Natural Systems, Queens College, 1981-82.

Teaching Experience: Director of Department of Energy sponsored Faculty Development Program for High School Teachers (1980).

Developed a course on environmental effects of chemical technology about one-third of which is focused on energy-related technologies including nuclear power, fossil fuels and solar energy.

Participating teacher in Federated Learning Communities program on technology, values and society.

Has taught a course on materials and methods in the teaching of chemistry and physics.

Has taught freshmen seminars on science and social values and on the role of the contemporary American university.

Has also taught a wide variety of undergraduate and graduate lecture and laboratory courses in the fields of spectroscopy, physical chemistry and general chemistry.

Research: Has performed research funded by the National Science Foundation, Air Force Office of Scientific Research and the Research Foundation of the State University of New York on vibrational spectroscopy, flash photolysis, photochemistry, and energy technologies. Co-leader of delegation invited to study scientific planning in the Peoples Republic of China during the summer of 1978. Present research is on the environmental effects of various energy-related technologies and agricultural practices.

Publications: Has published over twenty research papers in refereed scientific journals in the fields of vibrational spectroscopy, chemical kinetics and photochemistry. Has authored several articles in newspapers and popular journals on energy technologies and on scientific planning in China.

Coauthor of a textbook, A Search for Order in the Physical Universe, W.H. Freeman, San Francisco (1974). Russian translation published in Moscow (1977). Presently editing a text on controversial environmental issues for Dushkin Publishing Group.

Public Service: Frequent lecturer and participant in forums at local colleges, civic and community organizations and television and radio shows on energy demand, alternate energy, environmental effects of energy strategies, and science and social values. Guest lecturer on energy development in China at 1979 National Conference of the U.S. China Peoples' Friendship Association, Detroit, Michigan. Member of advisory committee on Solid Waste Disposal for the Town of Hempstead, N.Y.

Organizational Affiliations: American Chemical Society, American Association for the Advancement of Science, Science for the People, Port Jefferson Safe Energy Group, Member of Board of Directors of the Shoreham Opponents Coalition, and Member of Board of Directors of the Safe Energy Resource Center.

Dioxin Experience

Dr. Raymond D. Harbison is Professor and Director of the Interdisciplinary Toxicology Program at the University of Arkansas for Medical Sciences and the National Center for Toxicological Research. He conducts basic research on the toxicological effects of dioxins and has reviewed many health and safety and environmental matters concerned with dioxin contamination. Dr. Harbison has recently completed a study which identified some of the metabolites of dioxin using animal models. He serves as a member of the National Institute of Occupational Safety and Health advisory group. In this capacity he has reviewed many proposals for the study of the effects of dioxins on workers as well as studies to investigate the efficacy of protective equipment against dioxin penetration. Dr. Harbison also serves as a consultant to the U.S. Environmental Protection Agency. During the past 5 years he has reviewed site safety plans and safety procedures for management of dioxin contamination at hazardous waste sites and when incidentally found at hazardous material spills. He served on the Health and Safety Advisory Committee which recommended the safety procedures to be used while investigating the Times Beach dioxin contamination. He also assessed the risk associated with the dioxin contamination at Verona, Missouri (Denny Farm Site). Further he has directed the medical monitoring program for field personnel investigating hazardous waste sites contaminated with dioxin. He has also written reviews on the subject area of the general toxicity of chlorinated biphenyls and dioxin contaminants. Dr. Harbison has written more than 100 scientific papers and has an international reputation in the field of toxicology.

March 1983

CLARK WRIGHT HEATH, JR.
Curriculum Vitae

<u>Address</u>: Work: Office of the Director
Centers for Disease Control
Atlanta, Georgia 30333
Telephone:
404-329-3916

Home: 423 Woodhaven Drive
Decatur, Georgia 30030
404-373-9089

<u>Family</u>: Spouse: Janet
Children: Thomas
Andrew
Mary

Education

A.B., Oberlin College, Oberlin, Ohio, 1954
M.D., Johns Hopkins University School of Medicine, Baltimore, Maryland, 1958

Professional Training

Intern and resident in internal medicine, Boston City Hospital, II and IV Medical Services (Harvard), Boston, Massachusetts, 1958-1960

Epidemic Intelligence Service (EIS) Officer, U.S. Public Health Service, Communicable Disease Center, Atlanta, Georgia, 1960-1962

Resident in internal medicine, Boston City Hospital, II and IV Medical Services (Harvard), Boston Massachusetts, 1962-1963

Research Fellow, Tufts Hematology Laboratory, Boston City Hospital, Boston, Massachusetts, 1963-1965

Career Positions

Chief, Leukemia Section, Epidemiology Program, Center for Disease Control (CDC), Atlanta, Georgia, 1965-1972

Deputy Chief, Viral Diseases Branch, Epidemiology Program, CDC, 1968-1972

Chief, Cancer and Birth Defects Branch, Epidemiology Program, CDC, 1972-1975

Director, Chronic Diseases Division, Bureau of Epidemiology, CDC, 1975-1980

Director, Chronic Diseases Division, Center for Environmental Health, Centers for Disease Control, 1980-1982

Program Development Officer, Office of the Director, Centers for Disease Control, 1982 -

Academic Appointments

Assistant in Medicine, Harvard Medical School, Boston, Massachusetts, 1962-1963

Clinical Associate, Tufts University School of Medicine, Boston, Massachusetts, 1963-1965

Clinical Instructor in Medicine, Emory University School of Medicine, Atlanta, Georgia, 1965-1971

Clinical Assistant Professor of Medicine, Emory University School of Medicine, 1971-

Clinical Assistant Professor of Preventive Medicine, Emory University School of Medicine, 1971-1980

Clinical Associate Professor, Community Health, Emory University School of Medicine, 1981-

Visiting Professor, University of Minnesota, School of Public Health, Summer, 1981, 1982

Professional Organizations

American Association for the Advancement of Science
American Federation for Clinical Research
American Medical Association
American Public Health Association
National Scientific Research Society of America
Society for Epidemiologic Research
American Epidemiological Association
International Epidemiological Association

Boards

Georgia State Board of Medical Examiners
Qualifications completed, American Board of Internal Medicine
Fellow, American College of Epidemiology, 1981

Awards

PHS Meritorious Service Medal, HEW, May 19, 1978
HEW Certificate of Appreciation, March 15, 1979
PHS Certificate of Appreciation, 1979
CDC Medal of Excellence, 1979

Committees, Work Groups, and Consultations

Consultant, World Health Organization (WHO), Work Group on alpha chain disease, 1975
Contributing author: "Alpha-chain Disease and Related Small-Intestinal Lymphoma: a Memorandum," Bull WHO 54:615-624, 1976

Consultant, WHO, Epidemiology of alpha chain disease, Iran and Algeria, October 1976

Committees, Work Groups and, Consultations (continued)

Member, Second Task Force for Research Planning in Environmental Health, 1976
Author: Environmental health surveillance (background document for the Task Force)

Member, Epidemiology Work Group, Breast Cancer Task Force, National Cancer Institute, 1976-1978

Chairperson, Subcommittee on Polybrominated Biphenyls, Committee to Coordinate Environmental and Related Programs within the Public Health Service (CCERP), U.S. Public Health Service (USPHS), 1976-1978

Member, Task Force on Environmental Cancer and Heart and Lung Disease, 1978

Chairperson, Work Group on Science, Interagency Taskforce on the Health Effects of Ionizing Radiation, 1978-1979
Principal author: Report of the Work Group on Science, Interagency Task Force on the Health Effects of Ionizing Radiation. U.S. Department of Health, Education, and Welfare, June 1979, Washington, D.C., 132 p

Member, Interagency Radiation Research Committee (IRRC) (U. S. Government), 1979 -
Chairperson: IRRC study group to evaluate research proposals to study delayed health effects of fall-out radiation in Utah/Nevada/Arizona (1980).

Chairperson, Subcommittee on the Use of Long-term Registries for Health Followup of Populations Exposed to Toxic Hazards, CCERP, USPHS, 1981

Member, Steering Committee, Conference on Guidelines for Studies of Human Populations Exposed to Mutagenic and Reproductive Hazards, 1981

Chairperson, USPHS panel to advise the Environmental Protection Agency concerning health implications of environmental toxicologic testing at Love Canal, 1981 - 1982

Consultant, WHO, concerning epidemic in Spain of "toxic allergic syndrome" associated with cooking oil use, 1981, 1983

Experience in Teaching Epidemiology

Responsibility for teaching principles of chronic disease and analytic epidemiology in the annual Epidemic Intelligence Service course, CDC, 1972- (includes preparation of CDC syllabus entitled "Principles of Analytic Epidemiology" and several teaching exercises for class participation)

Prepared and taught a 3-week course in environmental epidemiology, University of Minnesota, summer 1981, 1982

Periodic lectures and class exercises, Emory University School of Medicine, 1965-

PUBICATIONS

1. Galton MM, Menges RW, Shotts EB Jr, Nahmias AF, Heath CW Jr: Lepto-spirosis: epidemiology, clinical manifestations in man and animals and methods in laboratory diagnosis. Public Health Service Publications, No. 951, 70 p, U.S. Government Printing Office, Washington, 1962.

2. Doege TC, Heath CW Jr, Sherman IL: Diphtheria in the United States, 1959-1960. Pediatrics 1962; 30:194-205.

3. Heath CW Jr, Zusman J: An outbreak of diphtheria among skid-row men. New Engl J Med 1962; 267:809-12.

4. Doege TC, Levy PS, Heath CW Jr: A diphtheria epidemic related to community immunization levels and the health problems of migrant workers. Public Health Reports 1963; 78:151-60.

5. Heath CW Jr, Hasterlik RJ: Leukemia among children in a suburban community. Am J Med 1963; 34:796-812.

6. Heath CW Jr, Zusman J, Sherman IL: Tetanus in the United States, 1950-1960. Am J Public Health 1964; 54:769-79.

7. Heath CW Jr, Manning MD, Zelkowitz L: Case clusters in the occurrence of leukemia and congenital malformations. Lancet 1964; 2:136-7.

8. Heath CW Jr, Moloney WC: Familial leukemia. Five cases of acute leukemia in three generations. New Engl J Med 1965; 272:882-7.

9. Fine RN, Wang MYFW, Heath CW Jr: Nuclear projections of neutrophils in the 13-15 trisomy syndrome. Pediatrics 1965; 35:712-4.

10. Heath CW Jr, Alexander AD, Galton MM: Leptospirosis in the United States. Analysis of 483 cases in man, 1949-1961. New Engl J Med 1965; 273:857-64, 915-22.

11. Heath CW Jr, Moloney WC: The Philadelphia chromosome in an unusual case of myeloproliferative disease. Blood 1965; 26:471-8.

12. Heath CW Jr, Moloney WC: Cytogenetic observations in a case of erythremic myelosis. Cancer 1965; 18:1495-504.

13. Heath CW Jr: Cytogenetic observations in vitamin B12 and folate deficiency. Blood 1966; 27:800-15.

14. Heath CW Jr: Epidemic leukaemia in man: community patterns of leukaemia occurrence. Proc XIth Cong of the Int Soc Haem, 1966, Sydney, pp 194-6.

15. Heath CW Jr: The significance of leukemia clusters. Hospital Practice 1968; 3:64-70.

16. Heath CW Jr: Formal discussion: epidemiology of acute leukemia and Burkitt's tumor. Cancer Res 1967; 27 (Part 1):2439-40.

17. Heath CW Jr, Bennett JM, Whang-Peng J, Berry EW, Wiernik PH: Cytogenetic findings in erythroleukemia. Blood 1969; 32:453-67.

18. Ebbin AJ, Heath CW Jr, Moldow RE, Lee J: Down's syndrome and leukemia in a family. J Pediat 1968; 73:917-20.

19. Falek A, Heath CW Jr, Ebbin AJ, McLean WR: Unilateral limb and skin deformities with congenital heart disease in two siblings: a lethal syndrome. J Pediat 1968; 73:910-3.

20. McPhedran P, Heath CW Jr, Lee J: Patterns of familial leukemia: ten cases of leukemia in two interrelated families. Cancer 1969; 24:403-7.

21. McPhedran P, Heath CW Jr: Multiple cases of leukemia associated with one house. J Am Med Assoc 1969; 209:2021-5.

22. Chen ATL, Ebbin AJ, Schimpeler S, Heath CW Jr, Falek A: Birth weight and mortality in Down's syndrome infants. Soc Biol 1969; 16:290-1.

23. McPhedran P, Heath CW Jr: Acute leukemia occurring during chronic lymphocytic leukemia. Blood 1970; 35:7-11.

24. McPhedran P, Heath CW Jr, Garcia JS: Racial variations in leukemia incidence among the elderly. J Nat Cancer Inst 1970; 45:25-8.

25. Heath CW Jr: Human leukemia: genetic and environmental clusters. Bibl Haemat 1970; 36:649-53.

26. Heath CW Jr, Alexander AD: Leptospirosis. In Volume II, Brenneman's Textbook of Pediatrics. Hagerstown, Harper and Row, 1970, pp 2-5.

27. Kyle RA, Herber L, Evatt BL, Heath CW Jr: Multiple myeloma: a community cluster. J Am Med Assoc 1970; 213:1339-41.

28. Potolsky AI, Heath CW Jr, Buckley CE III, Rowlands DT Jr: Lymphoreticular malignancies and immunologic abnormalities in a sibship. Am J Med 1971; 50:42-8.

29. Heath CW Jr: Epidemiologic implications of feline leukemia virus. J Am Vet Med Assoc 1971; 158:1119-22.

30. Evatt BL, Dowdle WR, Johnson M Jr, Heath CW Jr: Epidemic mycoplasma pneumonia. New Engl J Med 1971; 285:374-8.

31. Kyle RA, Heath CW Jr, Carbone P: Multiple myeloma in spouses. Arch Intern Med 1971; 127:944-6.

32. Heath CW Jr, Brodsky AL, Potolsky AI: Infectious mononucleosis in a general population. Am J Epidemiol 1972; 95:46-52.

33. McPhedran P, Heath CW Jr, Garcia J: Multiple myeloma incidence in metropolitan Atlanta, Georgia: racial and seasonal variations. Blood 1972; 39:866-73.

34. Brodsky AL, Heath CW Jr: Infectious mononucleosis: epidemiologic patterns at United States colleges and universities. Am J Epidemiol 1972; 96:87-93.

35. Heath CW Jr: Epidemiology of Hodgkin's disease (editorial). Ann Intern Med 1972; 77:313-4.

36. Heath CW Jr: Cancer as a sequel to therapy (editorial). New Engl J Med 287:1146-7.

37. Larsen RJ, Holmes CL, Heath CW Jr: A statistical test for measuring unimodal clustering. A description of the test and of its application to cases of acute leukemia in metropolitan Atlanta, Georgia. Biometrics 1973; 29:301-9.

38. Evatt BL, Chase GA, Heath CW Jr: Time-space clustering among cases of acute leukemia in two Georgia counties. Blood 1973; 41:265-72.

39. Heath CW Jr, Evatt BL: Observations concerning the time-space distribution of childhood acute leukemia in DeKalb County, Georgia. Trace Substances in Environmental Health VI, 1973; pp 23-7.

40. Heath CW Jr: Sick pets and human leukemia (editorial). Ann Intern Med 1973; 78:605.

41. Falletta JM, Fernbach DJ, Singer DB, South MA, Landing BH, Heath CW Jr, Shore NA, Barrett FF: A fatal X-linked recessive reticuloendothelial syndrome with hyperglobulinemia. J Pediat 1973; 83:549-56.

42. Heath CW Jr: Current epidemiologic evidence regarding known or suspected oncogenic viruses in relation to human cancer. In Hellman A, Oxman MN, Pollack R (eds): Biohazards in Biological Research. Cold Spring Harbor Laboratory, 1973, pp 205-8.

43. Brown TM Jr, Heath CW Jr: Time-space clustering among cases of Burkitt's tumor. Cancer Res 1974; 34:1216-8.

44. Falk H, Creech JL Jr, Heath CW Jr, Johnson MN, Key MM: Hepatic disease among workers at a vinyl chloride polymerization plant. J Am Med Assoc 1974; 230:59-63.

45. Randolph VI, Heath CW Jr: Influenza during pregnancy in relation to subsequent childhood leukemia and lymphoma. Am J Epidemiol 1974; 100:399-409.

46. Heath CW Jr, Falk H, Creech JL Jr: Characteristics of cases of angiosarcoma of the liver among vinyl chloride workers in the United States. Ann NY Acad Sci 1975; 246:231-6.

47. Heath CW Jr, Flynt JW Jr, Oakley GP Jr, Falek A: The role of birth defect surveillance in control of fetal environmental hazards. Postgrad Med J (Suppl 2) 1975; 51:69-77.

48. Heath CW Jr: Epidemiology of leukemia. In Schottenfeld D (ed): Cancer Epidemiology and Prevention: Current Concepts. Springfield, CC Thomas, 1975, pp 318-50.

49. Heath CW Jr, Caldwell GG, Feorino PC: Viruses and other microbes. In Fraumeni JF Jr (ed): Persons at High Risk of Cancer. An Approach to Cancer Etiology and Control. New York, Academic Press, 1975, pp 241-64.

50. Heath CW Jr: Hereditary factors in leukemia and lymphoma. In Lynch HT (ed): Cancer Genetics. Springfield, CC Thomas, 1976, pp 233-48.

51. Caldwell GG, Heath CW Jr: Case clustering in cancer. Southern Med J, 1976; 69:1598-602.

52. Brown TM Jr, Heath CW Jr, Lang RM, Lee SK, Whalley BW: Nasopharyngeal cancer in Bermuda. Cancer 1976; 37:1464-8.

53. Heath CW Jr: Epidemiologic implications of animal leukemia virus models for the human situation. Cancer Res 1976; 36:589-90.

54. Levine PH, Connelly R, Heath CW Jr, Caldwell GG, Terasaki PI, Mickey MR, Fabrizio P: An evaluation of antibody titers to the Epstein-Barr as a test for susceptibility to cancer. Proc 3rd Int Symp on Detection and Prevention of Cancer, New York, 1976, pp 1525-37.

55. Heath CW Jr: Carcinogens of industrial origin: occupational and non-occupational risks. In Nieburg HE (ed): Proceedings of the Third International Symposium on Detection and Prevention of Cancer. New York, Marcel Dekker, 1977.

56. Heath CW Jr, Dumont CR, Gamble J, Waxweiler RJ: Chromosomal damage in men occupationally exposed to vinyl chloride monomer and other chemicals. Environ Res 1977; 14:68-72.

57. Zack MM Jr, Heath CW Jr, Andrews MD, Grivas SA Jr, Christine BW: High school contact among persons with leukemia and lymphoma. J Natl Cancer Inst 1977; 59:1343-9.

58. Carter CD, Brown TM Jr, Herbert JT, Heath CW Jr: Cancer incidence following infectious mononucleosis. Am J Epidemiol 1977; 105:30-6.

59. Heath CW Jr: Industrial toxins and the community. Introductory comments. 37th Annual AMA Congress on Occupational Health, 1977.

60. Harrington JM, Blot WJ, Hoover RN, Housworth WJ, Heath CW Jr, Fraumeni JF Jr: Lung cancer in coastal Georgia: a death certificate analysis of occupation: brief communication. J Natl Cancer Inst 1978; 60:295-8.

61. Heath CW Jr: Environmental pollutants and the epidemiology of cancer. Environ Health Perspect 1978; 27:7-10.

62. Blot WJ, Harrington JM, Toledo A, Hoover R, Heath CW Jr, Fraumeni JF Jr: Lung cancer after employment in shipyards during World War II. New Engl J Med 1978; 299:620-4.

63. Landrigan PJ, Wilcox KR Jr, Silva J Jr, Humphrey HEB, Kauffman C, Heath CW Jr: Cohort study of Michigan residents exposed to polybrominated biphenyls: epidemiologic and immunologic findings. Ann NY Acad Sci 1979; 320:284-94.

64. Silva J, Kauffman CA, Simon DG, Landrigan PJ, Humphrey HEB, Heath CW Jr, Wilcox KR Jr, Van Arnburg G, Kaslow RA, Ringel A, Hoff K: Lymphocyte function in humans exposed to polybrominated biphenyls. J Reticuloend Soc 1979; 26:341-7.

65. Caldwell GG, Kelley DB, Heath CW Jr: Leukemia among participants in military maneuvers at a nuclear bomb test (Smoky). A preliminary report. J Am Med Assoc 1980; 244:1575-8.

66. Zack MM Jr, Heath CW Jr: Epidemiology and the 1980 census (editorial). Ann Int Med 1980; 92:562-3.

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70. Falk H, Herbert JT, Edmonds L, Heath CW Jr, Thomas LB, Popper H: Review of four cases of childhood hepatic angiosarcoma. Elevated environmental arsenic exposure in one case. Cancer, 1981; 47:382-91.

71. Heath CW Jr: The leukemias. In Schottenfeld D, Fraumeni J Jr (eds): Cancer Epidemiology and Prevention. Philadelphia, WB Saunders, 1982, pp 728-38.

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73. Caldwell GG, Heath CW Jr: Surveillance of infectious mononucleosis cases by use of existing data from state laboratories. Public Health Rep 1982; 97:579-82.

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75. Heath CW Jr: Carcinogenic effects of chemical and physical agents. Human observations. In Dardanoni L, Miller RW (eds): Plans for Clinical and Epidemiologic Follow-up after Area-wide Chemical Contamination. Proceedings of an International Workshop, Washington, DC, March 17-19, 1980. Washington, National Academy Press, 1982, pp 195-203.

76. Heath CW Jr: Epidemiology of gastrointestinal lymphomas. In Correa P, Haenszel W (eds): Epidemiology of Cancer of the Digestive Tract. Martinus Nijhoff, 1982, pp 148-59.

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78. Heath CW Jr: Field epidemiologic studies of populations exposed to waste dumps. Envir Health Perspect, in press.

79. Heath CW Jr: Pollution. McGraw Hill Year Book of Science and Technology, in press.

80. Heath CW Jr: Occupational and environmental diseases. Funk and Wagnalls New Encyclopedia, in press.

81. Heath CW Jr, Evatt BL: Haematopoietic diseases. In Holland W, Detels R, Knox G (eds): Textbook of Public Health. Oxford, Oxford University Press, in press

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1. Heath CW Jr, Manning MD: Leukemia outbreaks? Lancet 1964; 1:1394.

2. Heath CW Jr, Moloney WC: Familial leukemia: five cases of myelocytic leukemia in three generations. Xth Cong of Int Soc Hemat, 1964.

3. Heath CW Jr: Cytogenetic observations in pernicious anemia and folic acid deficiency. Clin Res 1965; 13:275.

4. Wang MYFW, Heath CW Jr, Desforges JF: Galactose-1-phosphate uridyl transferase in chronic myelogenous leukemia. Clin Res 1965; 13:341.

5. Heath CW Jr: Cytogenetic findings in the blast phase of chronic granulocytic leukemia. Meeting of the Commissioned Officer's Association, USPHS, 1967.

6. Heath CW Jr. Book review (Racial and geographical factors in tumour incidence) New Engl J Med 1968; 278:568-9.

7. Potolsky AI, Heath CW Jr: Familial leukemia and lymphoma. 96th Annual Meeting of the APHA, 1968. Also in Clin Res 1969; 17:33.

8. McPhedran P, Heath CW Jr: Patterns of familial leukemia. Clin Res 1969; 17:335.

9. Potolsky AI, Heath CW Jr, Buckley CE III, Rowlands DT Jr: Immunologic studies in familial leukemia. Clin Res 1969; 17:338.

10. Heath CW Jr, Falek A: Surveillance of birth defects in metropolitan Atlanta, Georgia. 3rd International Conference on Congenital Malformations, 1969.

11. Falletta JM, Fernbach DJ, Singer DB, Shore NA, Landing B, Heath CW Jr: An X-linked recessive "malignant" reticuloendotheliosis. Soc for Ped Res, 1970.

12. McPhedran P, Heath CW Jr: Incidence of multiple myeloma: racial and seasonal variations. Am Soc of Hemat, 1970.

13. Oakley GP Jr, Ebbin AJ, Flynt JW Jr, Schimpeler S, Falek A, Heath CW Jr: Incidence of Down's syndrome (mongolism) in Atlanta, 1960-69. Teratology Society, 1971.

14. Falek A, Flynt JW Jr, Heath CW Jr, Freeman M, Schwartz J: Comparison of congenital malformations between white and black newborns in Atlanta, Georgia. Int Cong of Human Genetics, 1971.

15. Flynt JW Jr, Heath CW Jr: Surveillance of congenital malformations: problems and perspective. Am Public Health Assoc, 1971.

16. Heath CW Jr, Rosenstock JG, Lobdell G: An epidemic of Hodgkin's disease? Lancet 1971; 2:426-7.

17. Heath CW Jr: Clusters of leukemia and Hodgkin's disease. New Engl J Med 1971; 285:1146-7.

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19. Heath CW Jr, Everett JR II, Stewart JR, Daines J, Daines PH: Clustering in Hodgkin's disease. Lancet 1973; 1:669-70.

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25. Heath CW Jr: Epidemiologic studies at Love Canal. Am Public Health Assoc, Detroit, 1980.

26. Heath CW Jr: Applying epidemiology to public health. Presented at Symposium Honoring Alexander D. Langmuir, University of Texas School of Public Health, 1982.

27. Heath CW Jr: The Spanish toxic syndrome. Am Epidemiol Soc, 1982.

CURRICULUM VITAE

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Germany

14-3-1933	born in Vienna, Austria
1947-1952	Polytechnic for Chemical Industry and Trade (Vienna Austria)
1952-1958	EBEWE Drug Co., Austria
1958	Emigration to Canada
1963	M.Sc. (Chemistry) University of Saskatchewan
1965	Ph.D. (Chemistry) Univ. of Saskatchewan
1965	Canadien Citizen
1965-1967	NIH-postdoctoral fellow in Biochemistry, Dept. of Plant Pathology, Univ. of California, Davis
1967-1974	Scientist, National Research Council of Canada, Halifax
1973-1974	Sabbatical leave, Technical University of Munich, Institute of Ecological Chemistry
1974-1983	Professor and Director, Laboratory of Environmental and Toxicological Chemistry, University of Amsterdam
Since 1983	Professor, Chair of Ecological Chemistry and Geochemistry, University of Bayreuth, Germany.

Otto Hutzinger: Activities related to polychlorinated dibenzo-p-dioxins (PCDD) and polychlorinated dibenzofurans (PCDF).

Since 1971	research on PCDD and PCDF
1977	first report on PCDD and PCDF in incinerator effluents resulting from work in my Amsterdam laboratory
1979	250.000 hfl grant from Dutch Ministry of the Environment to work on PCDD and PCDF in incinerator effluents
1980	expert witness on PCDD during 2,4,5-T cancellation hearings in Washington
Since 1980	on Organizing Committee for "International Symposium on Chlorinated Dioxins and Related Compounds". 1980 Rome (chairman and editor of proceedings), 1981 Washington, 1982 Salzburg (chairman and editor of proceedings), 1984 Ottawa, 1985 Bayreuth.
1981	Panel on PCDD, National Research Council of Canada (external advisor)
1982	Health and Welfare Canada / Environment Canada Advisory Committee on Dioxins (external advisor)
June 1983	Expert Group, Ministry of the Environment Rheinland Pfalz on PCDD containing waste dump Biebelsheim
July 1983	Peer Review workshop on Dioxin Documents for the US-EPA (panel member)
Summer 1983	Advisor to industrial client on PCDD and PCDF formation in wood burning operation

Since July 1983	Ontario Scientific Advisory Committee on Dioxins and Furans (Committee Member)
Sept. 1983	Conference on Health Effects of PCB (invited paper on thermal formation of PCDF and PCDD)
Dec. 1983	Dioxins in the Environment, Michigan State University (invited speaker)
Feb. 1984	400.000 DM grant from the German EPA, on formation of PCDD and PCDF in industrial processes

RÉSUMÉ

LOUIS JOSEPH THIBODEAUX
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PERSONAL DATA

Date of birth: November 13, 1939
Place of birth: Church Point, Louisiana
Home address: 1441 Oak Manor Dr., Fayetteville, AR
Home phone: (501) 521-3837
Wife: Elwana Joyce Lasiter
Place of birth: Wewoka, Oklahoma
Children: Jason Scott born Aug. 8, 1961
Michelle Renee born April 21, 1964
Hobbies: sailing, history, travel, hunting, country music
Social Security No.: 437-60-2801

EDUCATION

Ph.D., Chemical Engineering, Louisiana State University, 1968
M.S., Chemical Engineering, Louisiana State University, 1966
B.S., Petroleum-Chemical Engineering, Louisiana State University, 1962 (five-year course equivalent to separate degrees in each discipline).

PROFESSIONAL EXPERIENCE

Academic

Professor of Chemical Engineering, University of Arkansas; July 1977 to present
Visiting Professor of Chemical Engineering, University of Exeter, Exeter, England; January to June 1983
Associate Professor of Chemical Engineering, University of Arkansas; July 1972 to July 1977
Visiting Professor of Chemical Engineering, Oregon State University; August 1974 to January 1975
Assistant Professor, Chemical Engineering, University of Arkansas; January 1968 to July 1972
Assistant Professor, Civil Engineering (Environmental), University of Arkansas; Summer 1969, 1971
Research Assistant, National Council for Air and Stream Improvement, Division Engineering Research; Louisiana State University, Baton Rouge; June 1965 to February 1968
Research Assistant, Institute of Saline Studies, Division Engineering Research Louisiana State University, Baton Rouge; September 1964 to June 1965.

Consulting and Expert Witnessing
- Great Lakes Chemical, El Dorado, AR, 1983
- U.S. Corps of Engineers, Tacoma, WA, 1983
- Ethyl Corporation, Baton Rouge, LA, 1983
- Ethyl, Exxon, Dow, Petroprocessor vs USEPA, Baton Rouge, LA, 1983
- Arkansas Department Pollution Control and Ecology, USEPA vs Vertac Chemical, Little Rock, AR, 1979-1980
- Exxon Research and Engineering Company, Florham Park, NJ, 1979
- ESCOM Laboratory, Fayetteville, Arkansas, 1979
- McClelland Consulting Engineers, Fayetteville, Arkansas, 1979
- Monsanto Chemical Company, El Dorado, Arkansas, 1976
- Zero Mountain, Johnson, Arkansas, 1972
- Northwest Arkansas Regional Planning Commission, Springdale, Arkansas, 1971-72
- Daisy/Heddon, Rogers, Arkansas, 1971
- National Rejectors, Industries, Hot Springs, Arkansas, 1971
- Georgia Kraft Company, Rome Georgia, 1968-70

Full-time and Summer
- International Paper Company, Natchez, MI; Summer, 1970
- Georgia Kraft Company (Mead Corporation), Rome GA; Summer 1968 and 1969
- National Council Air and Stream Improvement, Baton Rouge, LA; Summers 1965, 1966, and 1967
- U.S. Rubber Company, Scotts Bluff, LA; Summer 1964
- E. I. duPont de Nemours and Company; Aiken, S.C.; June 1962 to February 1964

Organizations Memberships
- American Institute of Chemical Engineers
  - Technical Session Chair: Philadelphia, 1984; Washington, D.C., 1983; Tulsa, OK, 1974
  - Environmental Division Officer
    - Second Vice Chair, 1984
    - Treasurer, 1982 and 1983
    - Secretary, 1982
- American Chemical Society
  - Technical Session Chair: Miami, 1985, San Francisco, 1976
- American Water Resources Association
  - Meeting Program Chair (Ark. Section), 1972-1975
  - President (Ark. Section), 1975
- American Association Advancement of Science
- American Association University Professors
- Air Pollution Control Association
- American Society Engineering Education
- Society of Environmental Toxicology and Chemistry

Registrations
- Arkansas No. 4114
- Louisiana No. 11762

TEACHING AND EDUCATION EXPERIENCE

Undergraduate Courses (last 5 years)
- Chemical Processes and Kinetics
- Mass Transfer Principles
- Mass Transfer Applications

Graduate Courses (last 5 years)
- Advanced Mathematics for Chemical Engineers
- Transport Phenomena (Mass)
- Advanced Reactor Design
- Environmental Chemical Engineering (Chemodynamics)

Graduate Research Advisor
- Thesis advisor to 28 Masters Degree students
- Dissertation advisor to 4 Ph.D. Degree students

Continuing Education
- 4 Environmental Chemical Engineering courses (1969, 1971, 1979, 1981)
- 13 Chemodynamics short courses (1981, 1982, 1983)
  - 6 under AIChE sponsorship
  - 7 under University Missouri-Columbia sponsorship

Committees and University Service
- University Committees and Related Activities
  - Student Relations Committee-member
  - Hazardous Waste Committee-member
  - UA Chapter ΣXi-president
  - UA Chapter ΣXi-White paper to President of UA on Research-co-author
  - ORSP/ΣXi Research Proposal-Writing Seminar/Workshop-March 14-15, 1977 co-chairman
  - University Research Council-member
  - Graduate Council-member

- College of Engineering Committees
  - Service Course Committee
  - Tenure Committee
  - Computer Use (ad hoc)
  - Graduate curriculum committee
  - Engineering Math (ad hoc)

- Department of Chemical Engineering
  - Department Directions in Research (ad hoc)
  - Graduate Studies-co-chairman

CONTRIBUTIONS TO TECHNICAL LITERATURE

Doctoral Dissertation

"Ion-Exchange Resin Diffusion Coefficient and Resin Phase Ion Diffusivities", Jesse Coates, Advisor, Louisiana State University, Baton Rouge, 1968.

Book

CHEMODYNAMICS - Environmental Movement of Chemicals in Air, Water, and Soil, John Wiley, New York, (1979), 501 p.

Book Chapters

Thibodeaux, L. J., Chapter entitled: Chemodynamics, in the Handbook of Environmental Chemistry, Vol 2C, O. Hutzinger, Editor, Springer-Verlag, Berlin, WG (1984?)

Thibodeaux, L. J., and H. D. Scott, Chapter 4, Air/Soil Exchange Coefficients, in Environmental Exposure from Chemicals, W. Brock Neely and G. E. Blau, Editors, CRC Press, Inc., Boca Raton, FL (1984?)

Thibodeaux, L. J., C. Springer and S. Chatrathi, Chapter 17, Simulation Study of the Volatilization of Polychlorinated Biphenyls from Landfill Disposal Sites, in Environmental and Solid Waste, C.W. Francis and S.I. Auerbach, Editors, Butterworth Publishers, Woburn, MA (1983).

Thibodeaux, L. J., Chapter 5, Offsite Transport of 2,3,7,8-Tetrachlorodibenzo-p-dioxin from a Production Disposal Facility, in Chlorinated Dioxins and Dibenzofurans in the Total Environment, G. Choudhary, L. H. Keith and C. Rappe, Editors, Butterworth Publishers, Woburn, MA (1983).

Thibodeaux, L. J., L. K. Chang, D. J. Lewis, "Dissolution Rates of Organic Contaminants Located at the Sediment Interface of Rivers Streams, and Tidal Zones," Chapter 16 in Contaminants and Sediments, Vol. 1, R. A. Baker, Ed., Ann Arbor Science, Michigan, (1980).

Journal Articles

Thibodeaux, L. J., D. G. Parker and H. Heck, "A Flux Measurement Technique of Volatile Chemical Emissions from Surface Impoundments," Environmental Progress (accepted 11/17/83).

Hwang, S., and L. J. Thibodeaux, "Measuring Volatile Chemical Emission Rates from Large Waste Disposal Facilities," Environmental Progress, Vol. 2, No. 2, May 1983, p. 81.

Thibodeaux, L. J., and B. Becker, "Chemical Transport Rates Near the Sediment in Wastewater Impoundments," Environmental Progress, Vol. 1, No. 4, Nov. 1982, p. 296.

Thibodeaux, L. J., and P. S. Christy, "Spill of Soluble, High Density, Immiscible Chemicals In Rivers," Environmental Progress Vol. 1, No. 2, May, 1982, p. 12.

Thibodeaux, L. J., and S. Hwang, "A Model for Volatile Chemical Emissions to Air from Landfarming of Oily Waste," Environmental Progress Vol. 1, No. 1, Feb. 1982, p. 42.

Thibodeaux, L. J., C. Springer and L. M. Riley, "Models of Mechanisms for the Vapor Phase Emission of Hazardous oChemicals from Landfills," Journal Hazardous Materials, 7(1982) 63-74.

Thibodeaux, L. J., "Estimating the Air Emissions of Chemicals from Landfills," Jo. Haz. Materials, 4 (1981) 235-244.

Thibodeaux, L. J., "Fluid Dynamic Observations on a Packed Crossflow Cascade at High Loadings," Ind. Eng. Chem. Process Des. Dev., (1980) Vol. 19, 33-40.

Thibodeaux, L. J., K. Pittaway, "Measurements of the Oxygen Desorption Rate in a Single Stage Crossflow Packed Tower," Ind. Eng. Chem. Process Res. Dev., (1980), Vol. 19, p. 40-46.

Thibodeaux, L. J., J. D. Millican, "Quantity and Relative Desorption Rates of Air-Strippable Organics in Industrial Wastewater," Env. Sci. Tech., Vol. 11, No. 9, (September 1977), p. 879.

Thibodeaux, L. J., "Mechanisms and Idealized Dissolution Modes for High Density (p>1), Immiscible Chemicals Spilled in Flowing Water," AIChE Jr., Vol. 23, Nov 4, (July 1977), p. 544-553.

Thibodeaux, L. J., D. R. Daner, A. Kimura, J. D. Millican and R. J. Parikh, "Mass Transfer Units in Single and Multiple Stage Packed Bed, Cross-Flow Devices," Ind. Eng. Chem. Process Design and Development, Vol. 16, No. 3, (1977), p. 325.

Thibodeaux, L. J., and C. K. Chen, "A Fickian Analysis of Lake Sediment Upsurge," Water Resources Bulletin, Vol. 12, No. 2, April 1976.

Thibodeaux, L. J., "Semi-Infinite Solid Model for Prediction of Temperature in Deep Reservoirs and Lakes," Water Resources Bulletin, Vol. 11, No. 3, June 1975.

Thibodeaux, L. J., R. E. Estridge, B. G. Turner and R. L. Smathers, "Treatment of Selected Kraft Mill Waste in Cooling Towers," TAPPI, 54, 1, p. 53 (1971).

Thibodeaux, L. J., "Continuous Corsscurrent Mass Transfer in Towers," Chemical Engineering, Vol. 75, No. 12, June 1969, pp. 165-170.

Thibodeaux, L. J., W. C. McGlasson and H. F. Berger, "Potential Uses of Activated Carbon for Wastewater Renovation, TAPPI, 49, No. 12, pp. 521-526 (1966).

Thibodeaux, L. J., P. W. Murrill, "Comparing Packed and Plate Columns," Chemical Engineering, July 18, 1966.

Proceedings

Thibodeaux, L. J., C. Springer, and G. Hildebrand, "Air Emissions of Volatile Organic Chemicals From Landfills-A Pilot-Scale Study," 10th Annual Research Symposium, USEPA, Ft. Mitchell, KY, April 2-5, 1984.

Springer, C., L. J. Thibodeaux, P. D. Lunney and R. S. Parker, "Secondary Emissions from Hazardous Waste Disposal Lagoons: Field Measurements," 9th Annual Research Symposium, USEPA, Ft. Mitchell, KY, May 2-4, 1983.

Thibodeaux, L. J., C. Springer, P. Lunney, S. C. James and T. T. Shen, "Air Emissions Monitoring of Hazardous Waste Sites," Proceedings National Conference on Management of Uncontrolled Hazardous Waste Sites, Hazardous Materials Control Research Institute, Silver Spring, Maryland, 1982, p. 70-75.

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Thibodeaux, L. J., B. Kirsch and D. T. Mitchell, "Methodology of a Regional Industrial Waste-water Audit," presented at 28th Annual Purdue Industrial Waste Conference, West Lafayette, IN, May 1-3, 1973.

Thibodeaux, L. J., R. B. Estridge and B. G. Turner, "Simultaneous Stripping, Biochemical Oxidation and Cooling of Kraft Mill Wastewater," AIChE Symposium Series--Forest Products and the Environment, No. 133, Vol. 69, 1973.

Thibodeaux, L. J., "Measurement of the Relative Volatilization Rates of the Water-Miscible Fractions in an Aqueous Effluent," AIChE Symposium Series (WATER-1971) 68, 124, p. 169 (1972).

Thibodeaux, L. J., D. R. Smith and H. R. Berger, "Water Renovation Possibilities in the Pulp and Paper Industry," Chemical Engineering Progress Symposium Series 90 (AIChE), Vol. 64, 1968, pp. 178-186.

Reports and Bulletins

Thibodeaux, L. J., and D. Wolf, "Impact of High Chemical Contaminant Concentrations on Terrestrial and Aquatic Ecosystems: A State-of-the-Art Review," USEPA, Athens Environmental Research Lab., Athens, GA (1983).

Thibodeaux, L. J., C. Springer and P. D. Lunney, "Emission of Hazardous Chemicals from Surface Impoundments to Air," USEPA, Municipal Environmental Research Laboratory, June 1983 (in review).

Thibodeaux, L. J., D. G. Parker, and H. Heck, "Measurement of Volatile Chemical Emissions from Wastewater Basins," Final Report, U.S. Environmental Protection Agency, IREL, Cincinnati, OH, January, 1982, 79p.

Thibodeaux, L. J., "Spill of Soluble, High-Density, Immiscible Chemicals in Water," DOT/RSPA/DPB-50/78/25, U.S. Department of Transportation, Office of University Research, Washington, DC, (1978).

Thibodeaux, L. J., "The Quantity of High Volatile Constituents in Industrial Wastewater," Final Technical Letter Report for National Science Foundation, NSF-ENG 74-17316, Washington, D.C., July 1977, 6p.

Thibodeaux, L. J., "An Aqueous Environmental Simulation Model for Mid-South Lakes and Reservoirs," Water Resources Research Center Pub. No. 41, University of Arkansas, Fayetteville, Arkansas (1976).

Thibodeaux, L. J., "A Test Method of Volatile Component Stripping of Wastewater," Report EPA-660/2-74-044, U.S. Environmental Protection Agency, Washington, DC, (1974).

Thibodeaux, L. J., "Industrial Wastewater Survey-Northwest Arkansas Water Quality Management Study," Report No. NWARPC/UA-1, Northwest Arkansas Reg. Plan. Comm. Springdale, AR (1972).

Thibodeaux, L. J., C. Springer, T. Hedden and P. Lunney, "Chemical Volatilization Mechanisms from Surface Impoundments in the Absence of Wind," Proceedings of 8th Annual Research Symposium, U.S. Env. Protection Agency, Cincinnati, OH, (March 8-10, 1982).

Thibodeaux, L. J., "Transport of Pesticides and Related Chemicals Across Air-Water Interfaces" U.S.-USSR Symposium - Forecasting Behavior of Pesticides in the Environment, (accepted for publication U.S. EPA Lab, Athens, GA and to be published simultaneously in USSR), (October, 1981).

Thibodeaux, L. J., D. G. Parker, H. Heck. and R. Dickerson, "Quantifying Organic Emission Rate from Surface Impoundments with Micrometeorlogical and Concentrations Profile Measurements," Paper No. 127e, AIChE microfiche preprint in the Engineering Societies Library, United Engineering Center, 345 East 47th Street, New York, New Orleans Ann. Mtg., (Nov, 8-12, 1981).

Thibodeaux, L. J., R. Merrill and D. Wolbach, "Pentachlorophenol and Naphthalene Emissions to Air During Thermal Evaporation of Wastewater," Paper No. 1196 AIChE microfiche preprint in the Engineering Societies Library, United Engineering Center, 345 East 47th Street, New York, New Orleans Ann. Mtg. (Nov. 8-12, 1981).

Springer, C. S., and L. J. Thibodeaux, "Mechanisms and Models for Predicting the Desorption of Volatile Chemicals from Wastewater," Proceedings 7th Annual Symposium, U.S. Env. Protection Agency, MERL, Cincinnati, OH, (March 1981), p. 85-90.

Thibodeaux, L. J., D. Moncada, "Performance Comparison of A Crossflow Cascade and A Conventional Countercurrent Operation in Packed Towers," Paper 21st AIChE microfiche preprint in the Engineering Societies Library, United Engineering Center, 345 East 47th Street, New York, Chicago Ann. Mtg., (Nov. 16-20, 1980).

Thibodeaux, L. J., P. S. Christy, "The Spill of Sinker Chemicals - Laboratory Simulations," Proceedings of the 1980 Conference on Control of Hazardous Materials Spills, (May 13-15, 1980), Louisville, KY p. 369-374.

Thibodeaux, L. J., D. G. Parker, "Emission of Volatile Chemicals from Wastewater Plants," Special Report, National Council Air Stream Improvement, for Proceedings 1979 So. Regional Mtg., (June 6, 7, 1979), New Orleans, LA.

Thibodeaux, L. J., L. K. Chang, J. K. Harris, D. J. Lewis and M. W. Mourot, "Laboratory Results on the Spill of Soluble, High Density Chemicals on Water," Proceedings 4th Joint Conference on Sensing Environmental Pollutants, Washington, D.C. (1978), p. 511-514.

Thibodeaux, L. J., and D. G. Parker, "Desportion Limits of Selected Gases and Liquids from Aerated Basins," AIChE Symp. Series 156, Vol. 72, 1976.

Thibodeaux, L. J., "Air-Stripping of Organics from Wastewater: A Compendium," AIChE Proceedings of 2nd National Conference on Complete Water Reuse, May 5-8, 1975, Chicago, IL, p. 358.

Thibodeaux, L. J., "Preliminary Report on National Rejectors Industrial Wastewater Treatment Facilities and Practites," National Rejectors Inc., Hot Springs, Arkansas (August 1971).

Thibodeaux, L. J., "Natchez Mill Wastewater Improvement Studies," Final Report, International Paper Company, Natchez, Mississippi (September 1970).

Thibodeaux, L. J., and R. L. Wright, "Deionization of Paper Industry Wastewater by Ion Exchange," Special Report, Nat. Council Air Stream Imp., 103 Park Ave., New York, New York (May 1970).

Thibodeaux, L. J., and H. F. Berger, "Laboratory and Pilot Plant Studies on Water Reclamation," Tech. Bul. No. 203, Nat. Council Air Stream Imp., 103 Park Ave., New York, NY (July 1967).

Thibodeaux, L. J., "Improvement Study of Scotts Bluff Plant Effluent," Final Report, Naugatuck Chemical Co., Baton Rouge, LA, (August 1964).

TECHNICAL PRESENTATIONS

Thibodeaux, L. J., "Physical and Chemical Methods of Kraft Mill Wastewater Treatment," Seminar given to Department of Bio-Environmental Engineering, University of Florida, Gainesville, FL, August 1967.

Thibodeaux, L. J., "Water Pollution Prevention and Treatment," Interdisciplinary Toxicology Seminar, University of Arkansas Animal Science Center, Fayetteville, Arkansas, June 1969.

Thibodeaux, L. J., "Use of Chemical Engineering Design Procedures in Wastewater Treatment," Georgia WPCA Annual Conference, Savannah, Georgia, Sept. 20-23, 1970.

Thibodeaux, L. J., R. B. Estridge and B. G. Turner, "Measurement of the Relative Volatilization Rates of the Water-Miscible Fractions in an Aqueous Effluent," 69th National AIChE Meeting, Cincinnati, OH, May 16-19, 1971.

Thibodeaux, L. J., R. B. Estridge and B. G. Turner," Simultaneous Biochemical Oxidation, Stripping and Cooling of Kraft Mill Wastewater," 73rd National AIChE Meeting, Minneapolis, MN, August 1972.

Thibodeaux, L. J., "Review of Biotreating Processes for Wastewaters," 26th Annual Meeting, Bartlesville Section AIChE, Bartlesville, OK, March 25, 1972.

Thibodeaux, L. J., and N. J. Carter, "Coliform Emissions from Air/Water Contactors: A Preliminary Attempt to Establish Maximum Concentrations," AIChE Meeting, New York, NY, Fall 1972.

Thibodeaux, L. J., B. Kirsch, and D. Mitchell, "Methodology of a Regional Wastewater Audit," 28th Annual Purdue Industrial Waste Conference, West Lafayette, Indiana, May 1-3, 1973.

Thibodeaux, L. J., and D. G. Parker, "Desorption Limits of Selected Industrial Gases and Liquids from Aerated Basins," 76th National AIChE Meeting, Tulsa, OK, March 10-13, 1974.

Thibodeaux, L. J., and J. R. Jones, "A Test Method for Volatile Component Stripping of Wastewater," National AIchE Meeting, Salt Lake City, UT, Fall 1974.

Thibodeaux, L. J., "Air-Stripping of Organics from Wastewater-A Compendium," 2nd National Conference on Water Reuse, Chicaco, IL, May 5-8, 1975.

Thibodeaux, L. J., "Interphase Transport in the Natural Environment," AIChE Mid-Michigan Section, Midland Michigan, February 18, 1976.

Thibodeaux, L. J., and J. D. Millican, "Quantity and Relative Desorption Rates of the Air-Strippable Organics in Industrial Wastewater," ACS 172nd Meeting, San Francisco, California, August 29-September 3, 1976.

Spill of Sinker Chemicals in Flowing Water, March 12, 1977, Oklahoma Amer. Inst. Chemical Engr., Bartlesville, OK.

Mechanisms and Idealized Dissolution Modes for High Density ($p>1$), Immiscible Chemicals Spilled in Flowing Water, March 23, 1977, 83rd National AIChE, Houston, TX.

Laboratory Results on the Spill of Soluble, High Density Chemicals in Water, Nov. 6-11, 1977, 4th Joint Conf. Sensing Environmental Pollution, New Orleans, TN.

Laboratory Observations of the Spill of Heavy Liquids ($p>1$) in Water Dec. 5-7, 1977, 33rd S.W. Amer. Chem. Soc., Little Rock, AR.

Fluid Dynamics of a Packed, Crossflow Cascade at High Loadings, February 26-March 1, 1978, 84th National AIChE, Atlanta, GA.

Fluid Dynamics and Oxygen Desorption Rates in a Crossflow Packed Column, March 22, 1978, Arkansas Section AIChE, Little Rock, AR.

Spill of Soluble, High Density Immiscible Chemicals on Water, June 6, 1978, Department of Transportation, U.S. Coast Guard, Washington, DC.

Measurement of the Oxygen Desorption Rate in a Single Stage Crossflow Packed Tower, September 10-15, 1978, Amer. Chem. Soc., Miami, FL.

Dissolution Rates of Organic Contaminants Located at the Sediment Interface Rivers, Streams, and Tidal Zones, April 6-13, 1979, Amer. Chem. Soc., Honolulu, HI.

Review of Crossflow Mass-Transfer, May 10, 1979, Norton Chemical Co., Cleveland, OH.

Dissolution Processes in an Unstratified Lake, May 14-15, 1979, Amer. Water Resources Association, Arkadelphia, AR.

Thibodeaux, L. J., and C. Springer, "Air Emission Monitoring of Hazardous Wastes Sites" at National Conference on Management of Uncontrolled Hazardous Wastes Sites, Washington, D.C. (Nov., 1982).

Thibodeaux, L. J., "Chemodynamics at Environmental Interfaces-the Mass Transport Aspects," Monsanto Company Technical Community, St. Louis, MO, Nov. 8, 1982.

Thibodeaux, L. J., "Chemicals in the Environmental," University de Santiago, Santiago de Compostela, Spain, April 19, 1983.

Thibodeaux, L. J., "Hazardous Chemicals in the Environment: Mass Transfer Aspects," University of Exeter, Exeter, England, April 29, 1983.

Thibodeaux, L. J., "Chemical Engineering Research in Hazardous Waste," 7th Anniversary Symp. Arkansas Chemical Industry, Little Rock, AR, Oct. 27-28, 1983.

SPONSORED RESEARCH PROJECTS

Title: Northwest Arkansas Water Quality Management Study-Industrial Wastewater Survey
Agency: U.S. EPA
Period of Support: 1970-72
Total Dollars: $30,000

Title: A Test Method of Volatile Component Stripping of Wastewater in Cooling Towers
Agency: U.S. EPA
Period of Support: 1972-73
Annual Dollars: $38,538
Total Dollars: $38,538

Title: The Quantity of Highly Volatile Constituents in Industrial Wastewaters
Agency: National Science Foundation
Period of Support: 1975-76
Annual Dollars: $24,185
Total Dollars: $24,185

Title: An Aqueous Environmental Simulation Model for Mid-South Lakes and Reservoirs
Agency: U.S. Dept. Interior
Period of Support: 1973-76
Annual Dollars: $7,079
Total Dollars: $21,237

Title: Spill of Soluble High Density, Immiscible Chemicals on Water
Agency: USCG, DOT
Period of Support and Annual Dollars: 1977 - $48,520
1978 - $46,654, 1979 - $10,642
Total Dollars: $105,816

Title: Measurement of Volatile Chemical Emissions from Wastewater Basins
Agency: U.S. EPA
Period of Support: 1977, 1978, 1979 (Extension)
Total Dollars: $127,782

Title: Emission of Hazardous Chemicals from Surface and Near Surface Impoundments into Air
Agency: U.S. EPA
Period of Support and Annual Dollars: 1980-81 $156,872
1981-82 $148,457, 1982-83 $154,238
Total Dollars: $459,567

Title: Impact of High Chemical Contaminant Concentrations on Terrestrial and Aquatic Ecosystems: A State-of-the Art Review"
Agency: U.S. EPA
Period of Support and Annual Dollars: 1982-83 $16,381
Total Dollars: $16,381

Title: Investigation of Volatile Organic Chemical Emission Control Methods from Hazardous Waste Disposal Operations
Agency: U.S. EPA
Period of Support: 1983-1985
Total Dollars: $262,888

AWARDS, HONORS

1974 Awarded off-campus-duty-assignment to Oregon State University
1977-78 Elected President Sigma Xi, UA Chapter
1979-80 Dr. Yoshishi Hayashi, Visiting Professor, Kanazawa, Japan to UA research on crossflow mass transfer
1982 College of Engineering, Outstanding Research in Chemical Engineering ($1000)
1982 University of Arkansas Alumni Award, Outstanding Researcher and Teacher ($1000)
1982 Halliburton Company Award for Excellence in Research
1983 Awarded off-campus-duty-assignment to University of Exeter, Exeter, England
1983 Dr. Hans Schecker, Visiting Professor, University of Dartmund, W. Germany, to UA, study environmental chemical engineering research activities

ADVISORY COMMITTEES, PANELS, DELEGATIONS

State of Arkansas Hazardous Waste Technical Advisory Committee, member appointed by W. Clinton, Governor (Dec. 1979 to Dec. 1981)

AIChE, ad hoc committee, National Academy of Sciences/EPA Study on Disposal of Hazardous Industrial Waste-member of funds solicitation committee (March-October, 1980).

U.S. Environmental Protection Agency, Environmental Research Laboratory, Athens, GA - reviewer for Technology Development Applications Branch, Pesticide Exposure Assessment Technology, February 19, 1983.

Panel discussion member: Major Technical Issues Relating to the Land Disposal of Hazardous Waste, Arlington, VA, May 18-22, 1981.

Delegation member: USA-USSR Symposium: "Prediction of Pesticide Behavior in the Environment," Yerevan, Armenia SSR, Oct. 18-31, 1981.

Member, workshop: Determining the Field Applicability of Environmental Assessment Methods, U.S.EPA, Washington, DC, March 15-19, 1982.

Member, EPA Level I and II Exposure Assessment Workshop, Washington, DC, April 6-7, 1982 and Atlanta, GA, April 27-29, 1982.

Member Scientific Advisory Committee of Hazardous Waste Research Center, Louisiana State University, Baton Rouge, LA, 1982-83.

Peer Review Panel: Dioxin Documents to Assess the Health Risk in Air and Water Media, U.S. EPA, Cincinnati, OH, July 27-29, 1983.

Emission of Volatile Organic Carbon and Reduced Sulfur Compounds from Wastewater Treatment Plants, June 6-7, 1979, National Council Air Stream Improvement So. Reg. Mtg., New Orleans, LA.

Sediment/Chemical Dissolution Processes in an Unstratified Lake, Sept. 17, 1979, UA ChE, Fayetteville, AR.

Measurement of Volatile Chemical Emissions from Wastewater Basins Oct. 29-30, 1979, U.S. Environmental Protection Agency, Industrial Research Environmental Lab., Cincinnati, OH.

Estimating the Air Emissions of Chemicals from Hazardous Waste Landfills, November 25-29, 1979, Annual Mtg. AIChE, San Francisco, CA.

A Review of Crossflow Mass-Transfer, February 29, 1980, Department of Chemical Engineering, University-Missouri, Rolla, MO.

The Spill of Sinker Chemicals-Laboratory Simulations, May 13-15, 1980 Hazardous Spills Conference, Louisville, KY.

An Aerodynamic - Hydrodynamic Interaction Model of the Bottom Water Mass-Transfer Coefficient in Lakes and Similar Waterbodies, Aug. 24-29, 1980, Amer. Chem. Soc., Las Vegas, NV.

Chemodynamics - What we know and what we don't know, Sept. 22, 1980 UA ChE, Fayetteville, AR.

Spill of Soluble, High Density Immiscible Chemicals on Water, Oct. 2, 1980, Department of Transportation, U.S. Coast Guard, Washington, D.C.

Performance Comparison of A Crossflow Cascade and a Conventional Countercurrent Operation in Packed Towers, Nov. 16-20, 1980, Annual Mtg., AIChE, Chicago, IL (delivered by D. Moncada).

Quantifying Organic Emission Rates from Surface Impoundments with Micrometeorlogical and Concentration Profile Measurements, Jan. 7, 1981, U.S. Environmental Protection Agency, RTP, Durham, NC.

Chemodynamics - What we know and what we don't know, March 5, 1981 Dept. of Chemical Engineering, OK State University, Stillwater, OK.

Models of Mechanisms for Hazardous Chemical Emissions from Landfills, March 29-April 3, 1981, Amer. Chem. Soc., Atlanta, GA.

Chemodynamics - What we know and what we don't know, April 29, 1981, Rensleaar Poly. Institute, Troy, NY

Chemodynamics - What we know and what we don't know, May 19, 1982, Dow Chemical, Freeport, TX

Chemodynamics - What we know and what we don't know, June 10, 1981, Department of Chemical Engineering, Tech. High School, Zurich, Switzerland.

Gas-Side Mass-Transfer Coefficient and Interfacial Phenomena of Flat-Bladed Surface Agitators, Oct. 4-9, 1981, Second World Congress Chem. Engr. Montreal Canada (delivered by James Reinhardt).

Gas Crossflow Distillation in Packed Towers, Oct. 4-9, 1981, Second World Congress Chem. Engr., Montreal, Canada (delivered by Bruce Eldridge).

Transport of Pesticides and Related Chemicals Across Air-Water Interfaces, Oct. 17-31, 1981 US-USSR Symposium on Transport of Pesticides in the Environment, Yerevan, Armenia SSR.

Spill of Soluble, High Density, Immiscible Chemicals in Rivers, Nov. 8-11, 1981, Ann. Mtg. AIChE, New Orleans (delivered by Pattie S. Christy).

Pentachlorophenol and Naphthalene Emissions to Air During Thermal Evaporation of Wastewater, Nov. 8-11, 1981, Ann. Mtg. AIChE, New Orleans, LA.

A Model for Volatile Chemical Emissions to Air from Landfarming of Oily Waste, Nov. 8-11, 1981, Ann. Mtg. AIChE, New Orleans, LA.

Quantifying Organic Emission Rate from Surface Impoundment with Micrometeorological and Concentration Profile Measurements, Nov. 8-11, 1981, Ann. Mtg., AIChE, New Orleans, LA.

A Simulation Study of the Volatilization of Polychlorinated Biphenyls from Landfill Disposal Sites, October 4-8, 1981, 4th Annual Oak Ridge National Laboratory Life Sciences Symposium on Environment and Solid Waste, Oak Ridge, TN (deliered by C. Springer).

Mechanisms and Models for Predicting the Desorption of Volatile Chemicals from Wastewater, 7th Annual Research Symposium, U.S. Envir. Protection Agency, March 16-18, 1981, Philadelphia, PA (delivered by C. Springer).

Chemical Volatilization Mechanisms from Surface Impoundments in the Absence of Wind, March 8-10, 1982, 8th Annual Research Symposium U.S. Environmental Protection Agency, Cincinnati, OH.

Measurement of Volatile Chemical Emissions from Aerated Stabilization Basins, National Conference on Environmental Engineering, Env. Engr. Div. ASCE, Atlanta, GA, July 1981 (presented by H. Heck).

Thibodeaux, L. J., and C. Springer, presented "Identification of Volatilization Mechanisms" at EPA Research Symposium in Cincinnati, OH, (Feb., 1982)

Thibodeaux, L. J., "Off-site Transport of 2,3,7,8-Tetrachlorodibenzo-p-dioxin from a Production Disposal Facility" was presented at the American Chemical Society Meeting at Kansas City, (Sept. 1982).

CURRICULUM VITAE

Name: Arthur Canfield Upton

Date & Place of Birth: February 27, 1923, Ann Arbor, Michigan

Marital Status: Married, March 1, 1946, to Elizabeth Perry

Children: Rebecca, Melissa, Bradley

Military Record: Army U.S., 1943-1946
Capt. USAF Reserve, 1955-1970

Education: B.A., University of Michigan, 1944
M.D., University of Michigan, 1946

Positions Held:

1947- -- Intern, University Hospital, Ann Arbor, Michigan
1948-1950 -- Resident in Pathology, University of Michigan
1950-1951 -- Instructor in Pathology, University of Michigan
1951-1954 -- Pathologist, Biology Division, Oak Ridge National Laboratory
1954-1969 -- Chief, Pathology-Physiology Section, Biology Division, Oak Ridge National Laboratory
1969-1977 -- Professor of Pathology, State University of New York at Stony Brook
1969-1970 -- Chairman, Department of Pathology, State University of New York at Stony Brook
1970-1975 -- Dean, School of Basic Health Sciences, State University of New York at Stony Brook
1969-1977 -- Associate Pathologist, Medical Department, Brookhaven National Laboratory
1977-1979 -- Director, National Cancer Institute
1980- -- Director, Institute of Environmental Medicine, New York University
1980- -- Professor and Chairman, Department of Environmental Medicine, New York University, School of Medicine

Honors and Awards:

Alpha Omega Alpha
Phi Beta Kappa
Ciba Foundation Lecturer, 1959
E. W. Lawrence Award, 1965
Peruvian Oncology Society, 1967
Failla Lecturer, Radiation Research Society, 1977
Comfort Crookshank Award for Cancer Research, 1978
Japanese Cancer Association, 1979
Institute of Medicine, National Academy of Sciences, 1979
Claude M. Fuess Award, 1980
IBM-Princess Takamatsu Cancer Research Foundation, Lecturer, 1981

Membership in National Scientific Societies:

American Association for Advancement of Science
American Association for Cancer Research
American Association of Pathologists and Bacteriologists
American College of Toxicology
American Society for Experimental Pathology
Collegium Ramazzini
Gerontological Society
Harvey Society
International Academy of Pathology
New York Pathological Society
Permanent Commission and International Accociation on Occupational Health
Peruvian Society of Oncology, Honorary Member
Radiation Research Society
Scientific Research Society of America (RESA)
Society for Experimental Biology and Medicine
Society for Risk Analysis

Offices Held in National Scientific Societies:

American Association for Cancer Research:
    Board of Directors, 1961-1964
    Vice-President, 1962-1963
    President, 1963-1964

Representative to USA National Academy of Sciences-National Research Council: 1967-1969

Representative to USA National Committee on the International Union Against Cancer: 1972-1975

American Society for Experimental Pathology:
    Councilor, 1965
    Vice-President, 1966-1967
    President, 1967-1968

Radiation Research Society:
    Councilor, Medicine, 1963-1964
    Vice-President, 1964-1965
    President, 1965-1966

International Association for Radiation Research:
    Vice-President, 1979-1983
    President, 1983-

Editorial Boards:

Cancer Research, 1960-1964
Radiation Research, 1961-1964
Laboratory Investigation, 1961-1975
Nuclear Medicine, Excerpta Medica, 1964-1977
International Journal of Cancer, International Union Against Cancer, 1965-1974
Proceedings of the Society for Experimental Biology and Medicine, 1965-1968
Cancer, 1977-
Forum on Medicine, 1978-1982
American Journal of Industrial Medicine, Associate Editor, 1980-
Gerontology and Geriatrics Education, 1980-
American Society of Preventive Oncology, Publications Committee, 1980-
Risk Analysis, 1980-
SciQuest, 1981-1982
Environmental Research, 1981-

Committees:

National Academy of Sciences-National Research Council, Subcommittee on Long-Term Effects of Ionizing Radiation from External Sources, 1957-1960
American Cancer Society, Advisory Committee on Research on Etiology of Cancer, 1958-1961
U.S. Air Force, Life Sciences Working Group, 1958-1960
National Committee on Radiological Protection, Subcommittee on Relative Biological Effectiveness (M-4), 1958-1962
International Commission on Radiological Protection, Committee on Radiation Biology, 1960-1962
International Commission on Radiological Protection, Subcommittee on Relative Biological Effectiveness, 1960-1962
U.S. Public Health Service, National Advisory Committee on Radiation, 1961-1965
National Academy of Sciences-National Research Council, Ad Hoc Advisory Committee on Radiation Pathology, Chairman, 1962-1964
National Academy of Sciences-National Research Council, Committee on Pathology, 1962-1972
International Cancer Research Commission on the International Union Against Cancer, Expert Panel on Carcinogenicity, 1963
International Commission on Radiological Protection, Committee I, The Committee on Radiation Effects, 1963-, Vice-Chairman, 1965-1973; Chairman, 1973-1978
International Commission on Radiological Protection, Committee I, Task Group on the Biological Effects of High Energy Radiations, Chairman, 1963-1965
Executive Office of the President, Office of Science and Technology, NIH Study Committee Panel on Pathology, 1964
National Academy of Sciences-National Research Council, Advisory Committee to Federal Radiation Council, Chairman, 1964-1966; 1968-1971

National Council for Radiation Protection and Measurements, 1965-1977; 1980-
International Commission on Radiological Protection, Task Group on the Radiosensitivity of Different Tissues in Relation to Radiation Protection, 1966-1968
Federal Aviation Administration, Standing Committee for Radiation Biology Aspects of the SST, 1967-1970
National Cancer Institute, Ad Hoc Discussion Group on Recruitment and Training in Chemical Carcinogenesis, Chairman, 1967-1968
American Cancer Society, Tennessee Division, Board of Directors, 1967-1969
National Academy of Sciences-National Research Council, Division of Medical Sciences, 1967-1972; Executive Committee, 1968-1972
National Academy of Sciences-National Research Council, NASA Life Sciences Review Program Committee, 1970
National Cancer Institute, Cancer Research Training Committee, 1970-1971
Smithsonian Institution, Interdisciplinary Communications Program, Carcinogenesis Core Group, 1970-1973
Steering Committee of Los Alamos Meson Physics Facilities, Subcommittee on Whole Animal Radiation Biology and Pathology, 1971-1977
National Academy of Sciences-National Research Council, Advisory Committee on the Biological Effects of Ionizing Radiation, 1971-1977
National Academy of Sciences-National Research Council, Committee on the Biological Effects on Ionizing Radiation, Subcommittee on Somatic Effects, Chairman, 1971-1977
National Academy of Sciences-National Research Council, Committee on Pathology, Subcommittee on Environmental Pathology, Chairman, 1971-1972
Argonne Universities Association Review Committee, Biological and Medical Research Division, Argonne National Laboratory, 1971-1973
Argonne National Laboratory, Advisory Committee for the Center on Human Radiobiology, 1972-1977
Federation of American Societies for Experimental Biology, Life Sciences, Research Office, Advisory Committee, 1972-1977; Chairman, 1974-1977
National Cancer Institute, Carcinogenesis Advisory Panel, 1972-1973
National Cancer Institute, Division of Cancer Biology and Diagnosis, Board of Scientific Counsellors, 1973-1977
International Commission on Radiological Protection, Main Commission, 1973-1978; Committee, 1979-
Scientific Advisory Group, U.S.-Japan Cooperative Cancer Research Program, 1974-1977
National Center for Toxicological Research, Scientific Advisory Board 1974-1977
U.S.-Japan Radiation Effects Research Foundation, Scientific Council, 1975-1977; 1980-
World Health Organization, International Agency for Research on Cancer, Scientific Council, 1975-1977; Governing Council, 1977-1979
Environmental Protection Agency, Administrator's Pesticide Policy Advisory Committee, 1975-1977

International Commission for Protection Against Environmental Mutagens and Carcinogens, 1978-1979; 1980-
General Motors Cancer Research Foundation, Awards Assembly, 1978-1981
Institute of Medicine, National Academy of Sciences, 1979-
March of Dimes, Advisory Committee on Reproductive Hazards in the Workplace, 1980-1982
National Academy of Sciences-National Research Council, Advisory Committee on the Radiation Effects Research Foundation, Chairman, 1980-
Oak Ridge National Laboratory, Biology Division Advisory Committee, 1980-
Northwestern University Cancer Center, External Advisory Committee on Commonwealth Edison Study, 1980-
Brookhaven National Laboratory, Medical Department Visiting Committee, 1980-
GTE Laboratories, Technical Advisory Council, Steering Committee, 1980-1982
Department of Energy, Ad Hoc Advisory Board on Melanoma, 1980-1981
Governor's Committee on Love Canal, State of New York, 1980
National Academy of Sciences-National Research Council, Assembly of Life Sciences, 1980-1983
National Academy of Sciences-National Research Council, Commission on Life Sciences, 1983-
National Academy of Sciences-National Research Council, Committee on Priority Mechanisms, Chairman, 1980-1983
Exxon Corporation, Medical Department, Science Advisory Board, Chairman, 1980-
National Academy of Sciences-National Research Council, Assembly of Life Sciences, Panel on Hiroshima/Nagasaki Occupation Forces, 1980-1981
Johns Hopkins University, Nuclear Shipyard Workers Study, Technical Advisory Panel, Chairman, 1980-
New York State Department of Health, Health Research Council, 1981; Chairman, 1982-
American Health Foundation, Scientific Advisory Board, 1981-
American Association for Cancer Research, Public Issues Committee, Chairman, 1981-
The Permanent Commission and International Association on Occupational Health, Committee on Occupational Carcinogenesis, 1981-
Robert Wood Johnson Foundation, National Hospice Study, National Advisory Committee, 1981-
Three Mile Island Unit 2 Safety Advisory Board, 1981-1982
Harvard University, School of Public Health Overseers' Committee, 1981-
National Academy of Sciences-National Research Council, Steering Committee on Identification of Toxic and Potentially Toxic Chemicals for Consideration by the National Toxicology Program, 1981-
Labor Policy Insitute Advisory Board, 1982-
Associated Universities, Inc., Council for Research Planning in Biological Sciences, Board of Directors, 1982-
World Resources Institute, Board of Directors, 1982-
Third Task Force for Research Planning in Environmental Health Sciences, National Institute of Environmental Health Sciences, Chairman, 1983-

BIBLIOGRAPHY

Arthur C. Upton, M.D.

1. Upton, A.C. and Zarafonetis, C.J.D.: Histologic Findings in Rats Subjected to Prolonged Administration of Para-Aminobenzoic Acid. _Proceedings of the Society for Experimental Biology and Medicine 75_:450-452, 1950.

2. Upton, A.C.: Taenial Proglottides in the Appendix: Possible Association with Appendicitis. _American Journal of Clinical Pathology 20_:1117-1120, 1950.

3. Upton, A.C., and Coon, W.W.: Effects of Cortisone and Adrenocorticotrophic Hormone on Wound Healing in Normal and Scorbutic Guinea Pigs. _Proceedings of the Society for Experimental Biology and Medicine 77_:153-156, 1951.

4. Coon, W.W., and Upton, A.C.: Histochemical Studies of Wound Healing in Scurvy: Effects of Adrenocorticotrophic Hormone (ACTH) and Cortisone. _In_: _Surgical Forum_. W. B Saunders, Philadelphia, 1951, pp. 493-499.

5. Upton, A.C.: Histochemical Investigation of the Mesenchymal Lesions in Whipple's Disease. _American Journal of Clinical Pathology 22_:755-764, 1952.

6. Upton, A.C. and Furth, J.: A Transmissable Disease in Mice Characterized by Anemia, Leukopenia, and Erythropoietic Splenomegaly. _Federation Proceedings 11_:430-431, 1952.

7. Furth, J., Gadsden, E.L., and Upton, A.C.: Hyperplasia and Cystic Dilatation of Extrahepatic Biliary Tracts in Mice Bearing Grafted Pituitary Growths. _Cancer Research 12_:739-743, 1952.

8. Burnett, Jr., W.T., Burke, Jr., A.W., and Upton, A.C.: Protective Effect of Acetyl-Beta-Methylcholine, Carbamylcholine and Atropine on X-Irradiated Mice. _American Journal of Physiology 174_:254-258, 1953.

9. Upton, A.C. and Gude, W.D.: Changes of Dermal Connective Tissue After Total-Body Irradiation. _Federation Proceedings 12_:405, 1953.

10. Upton, A.C., Christenberry, K.W., and Furth, J.: Comparison of Local and Systemic Exposures in Production of Radiation Cataract. _A.M.A. Archives Ophthalmology 49_:164-167, 1953.

11. Furth, J. and Upton, A.C.: Vertebrate Radiobiology: Histopathology and Carcinogenesis. _Annual Review of Nuclear Science 3_:303-338, 1953.

12. Upton, A.C. and Furth, J.: Induction of Pituitary Tumors by Means of Ionizing Irradiation. *Proceedings of the Society for Experimental Biology and Medicine 84*:255-257, 1953.

13. Furth, J., Gadsen, E.L., and Upton, A.C.: ACTH Secreting Transplantable Pituitary Tumors. *Proceedings of the Society for Experimental Biology and Medicine 84*:253-254, 1953.

14. Upton, A.C.: (Book Review) *Biological Effects of External X and Gamma Radiation*, Part 1. R. E. Zirkle (Ed.), McGraw-Hill, New York, 1954. *Nucleonics 12*:78, 1954.

15. Moshman, J. and Upton, A.C.: Depigmentation of Hair as a Biological Radiation Dosimeter. *Science 119*:186-187, 1954.

16. Upton, A.C. and Furth, J.: The Effects of Cortisone on the Development of Spontaneous Leukemia in Mice and on Its Induction by Irradiation. *Blood 9*:686-695, 1954.

17. Upton, A.C. and Gude, W.D.: Physiologic and Histochemical Changes in Connective Tissue of Rat Induced by Total Body Irradiation. *A.M.A. Archives of Pathology 58*:258-264, 1954.

18. Upton, A.C., Furth, J., and Christenberry, K.W.: Late Effects of Thermal Neutron Irradiation in Mice. *Cancer Research 14*:682-690, 1954.

19. Furth, J., Upton, A.C., Christenberry, K.W., Benedict, W.H., and Moshman, J.: Some Late Effects in Mice of Ionizing Radiation from an Experimental Nuclear Detonation. *Radiology 63*:562-570, 1954.

20. Furth, J. and Upton, A.C.: Leukemogenesis by Ionizing Irradiation. *Acta Radiologica, Suppl. 116*:469-476, 1954.

21. Upton, A.C. and Furth, J.: A Transmissible Disease of Mice Characterized by Anemia, Leukopenia, Splenomegaly and Myelosclerosis. *Acta Haematologica 13*:65-76, 1955.

22. Upton, A.C. and Furth, J.: Spontaneous and Radiation-Induced Pituitary Adenomas of Mice. *Journal of the National Cancer Institute 15*:1005-1021, 1955.

23. Gude, W.D., Upton, A.C., and Odell, Jr., T.T.: Giemsa Staining of Autoradiograms Prepared with Stripping Film. *Stain Technology 30*:161-162, 1955.

24. Odell, Jr., T.T. and Upton, A.C.: Distribution of Calcium^{45} in Platelets and Bone Marrow of Rats. *Acta Haematologica 14*:291-293, 1955.

25. Upton, A.C.: The Pathogenesis of the Hemorrhagic State in Radiation Sickness: A Review. *Blood 10*:1156-1163, 1955.

26. Benedict, W.H., Christenberry, K.W., and Upton, A.C.: Spontaneous and Radiation-Induced Iris Atrophy in Mice. *American Journal of Ophthalmology 40*:163-169, 1955.

27. Hurst, G.S., Mills, W.A., Conte, F.P., and Upton, A.C: Principles and Techniques of Mixed Radiation Dosimetry - Application to Acute Lethality Studies of Mice with the Cyclotron. *Radiation Research 4*:49-64, 1956.

28. Upton, A.C., Conte, F.P., Hurst, G.S., and Mills, W.A.: The Relative Biological Effectiveness of Fast Neutrons, X-Rays, and γ-Rays for Acute Lethality in Mice. *Radiation Research 4*:117-131, 1956.

29. Upton, A.C., Furth, J., and Burnett, Jr. W.T.: Liver Damage and Hepatomas in Mice Produced by Radioactive Colloidal Gold. *Cancer Research 16*:211-215, 1956.

30. Upton, A.C., Melville, Jr., G.S., Slater, M., Conte, F.P., and Furth, J.: Leukemia Induction in Mice by Fast Neutron Irradiation. *Proceedings of the Society for Experimental Biology and Medicine 92*:436-438, 1956.

31. Gude, W.D., Upton, A.C., and Odell, Jr., T.T.: Blood Platelets of Human and Rat - A Cytochemical Study. *Laboratory Investigation 5*:348-358, 1956.

32. Upton, A.C. and Odell, Jr., T.T.: Utilization of S^{35}-Labeled Sulfate in Scorbutic Guinea Pigs. *A.M.A. Archives of Pathology 62*:194-199, 1956.

33. Clifton, K.H., Bloch, E., Upton, A.C., and Furth, J.: Transplantable Leydig-Cell Tumors in Mice. *A.M.A. Archives of Pathology 62*:354-368, 1956.

34. Conte, F.P., Melville, Jr., G.S., and Upton, A.C.: Effects of Graded Doses of Whole-Body X-Irradiation on Mast Cells in the Rat Mesentery. *American Journal of Physiology 187*:160-162, 1956.

35. Upton, A.C., Christenberry, K.W., Melville, G.S., Furth, J., and Hurst, G.S.: The Relative Biological Effectiveness of Neutrons, X-Rays, and Gamma Rays for the Production of Lens Opacities: Observations on Mice, Rats, Guinea-Pigs, and Rabbits. *Radiology 67*:686-696, 1956.

36. Furth, J., Buffett, R.F., Banasiewicz-Rodriguez, M., and Upton, A.C.: Character of Agent Inducing Leukemia in Newborn Mice. *Proceedings of the Society for Experimental Biology and Medicine 93*:165-172, 1956.

37. Upton, A.C., Buffett, R.F., Furth, J., Doherty, D.G.: Radiation-Induced "Dental Death" in Mice. *Radiation Research 4*:475-479, 1956.

38. Upton, A.C., Congdon, C.C., and Hollaender, A.: Uber den Mechanismus des verzogert eintretenden Todes nach Totalkorperbestrahlung. (Mechanisms of Delayed Death from Total-Body Irradiation). *Atompraxis 1*:1-6, 1957.

39. Melville, Jr., G.S., Conte, F.P., Slater, M., and Upton, A.C.: Acute Lethality of Mice as Influenced by the Periodicity of Paired Exposures to Fast Neutrons or X Rays. *British Journal of Radiology 30*:196-199, 1957.

40. Upton, A.C. and Furth, J.: Host Factors in the Pathogenesis of Leukemia in Animals and in Man. *In*: *Proceedings of the Third National Cancer Conference*, J. B. Lippincott Company, Philadelphia, 1957, pp. 312-324.

41. Morris, D.M., Wolff, F.F., and Upton, A.C.: The Influence of the Thyroid Gland on the Survival of Rats and Mice Bearing Transplanted Lymphoid Leukemia. *Cancer Research 17*:325-328, 1957.

42. Upton, A.C.: Ionizing Radiation and the Aging Process - A Review. *Journal of Gerontology 12*:306-313, 1957.

43. Melville, Jr., G.S., Conte, F.P., and Upton, A.C.: Biphasic Hyperferremia Induced in Rats by X-Irradiation. *American Journal of Physiology 190*:17-18, 1957.

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CHARLES O. VELZY, P.E.
President

VELZY
Associates

SUMMARY

Mr. Velzy has over twenty-five years of experience in the design and operation of solid waste processing facilities. He has developed nationally recognized expertise in the fields of recovery of energy from solid waste and air pollution control. Based on his extensive design and field operation experience, he has authored numerous papers on the present status of solid waste management practices; co-authored with his father, Charles R. Velzy, the section on "Incineration" in Marks' Standard Handbook for Mechanical Engineers; and has served as an instructor in Resource Recovery and Incinerator Technology.

EXPERIENCE

Mr. Velzy, as Project Engineer for the mechanical design of the energy-from-waste plant in the Town of Hempstead, New York, developed the mass and heat balances; the furnace combustion chamber and boiler arrangements; and all mechanical design for the two 300 ton-per-day mass-burning, steam-producing units at the plant. Steam is produced for electrical power generation from the burning of as-received municipal solid waste.

Under his direction, engineering design modifications were made to two 300 ton-per-day, energy-from-waste units at the Merrick, New York, disposal plant; in addition to three 150 ton-per-day mass-burning units at Huntington, New York; and the Waterbury, Connecticut, facility which included co-disposal of solid waste and sludge, upgrading of air pollution control equipment, water treatment facilities, and air pollution control technology advice.

Mr. Velzy heads the Technical Advisory and Review Committee of the Firm, which oversees all Velzy solid waste management projects. Recent technical reviews include the Dutchess County, New York, Solid Waste Management Plan for a 400 ton-per-day, energy-from-waste pyrolysis facility; the Power Authority of the State of New York (PASNY) feasibility study for utilization of steam generated from municipal solid waste at the Indian Point-3 Nuclear Plant; and energy-from-waste feasibility studies for Richmond, Virginia, Franklin County, Massachusetts, and the Hampton, Virginia, Peninsula Planning Commission, in addition to the New York City Brooklyn Navy Yard Resource Recovery Facility. He also directed the overall technical review and preparation of a formal report for use in the bond prospectus for the Multi-Town project, Suffolk County, New York.

Mr. Velzy also has extensive experience in development and design of wastewater and industrial waste treatment facilities.

EDUCATION

B.S. - Mechanical Engineering, University of Illinois, 1953
B.S. - Civil Engineering, University of Illinois, 1960
M.S. - Sanitary Engineering, University of Illinois, 1959

CHARLES O. VELZY, P.E.
President

REGISTRATION

Professional Engineer: NY, MD, MA, PA, OH, IN, IL, DE, WI, VA, FL, NC, CT

HONORS

Diplomate - American Academy of Environmental Engineers
Fellow - American Society of Mechnaical Engineers
1980 - Engineer of Year, N.Y.S. Society of Prof. Engineers, Westchester Chapter

AFFILIATIONS

AWWA, ASME, ASCE, WPCF, NSPE, NWWA, APWA, AWRA, APCA, ASTM

APPENDIX F

Qualifications and Experience of Fred C. Hart Associates

QUALIFICATIONS

Fred C. Hart Associates, Inc. (FCHA) has developed specific expertise in the assessment of risks related to dioxin and has assigned a multidisciplinary team of professionals to this study. The firm's experience encompasses studies of dioxin contamination at field sites including the early investigative work at Verona, Missouri (in 1981) and other locations in Puerto Rico and Connecticut; selection by EPA to develop dioxin analytical protocols down to 30 parts per quadrillion at our high hazard laboratory and contaminant facility in Las Vegas; one of the nation's largest risk assessment practices for hazardous materials including risk assessments for insurance companies, industry, and USEPA; and broad experience in combustion chemistry and the measurement and control of hazardous air emissions from waste disposal facilities. Specifically:

- The study team includes chemical engineers, public health specialists, chemists, and biologists with expertise in the risks associated with hazardous waste in the environment. For example, Dr. David Lipsky, the principal investigator, has recently completed a dioxin sampling study in Puerto Rico and has delivered expert testimony on the health significance of dioxin levels.

- FCHA operates two U.S. Environmental Protection Agency High Hazard Laboratories, which are the only laboratories of their kind in the U.S. FCHA staff regularly process all high hazard dioxin samples collected throughout the U.S. by the USEPA. FCHA staff also develop nationally used protocols for handling high concentrations of hazardous chemicals. For example, our staff has developed performance evaluation standards for dioxin samples in three matrices: water, clay, and fish tissue. The lab will be developing standards for additional matrices in the future.

- FCHA has conducted extensive field studies and designed remedial engineering solutions for a major Connecticut Superfund site, at which dioxin was one of the waste materials of concern.

- FCHA performed early field sampling and analyses at the New Jersey and Missouri dioxin sites under contract to USEPA.

- FCHA is currently performing field sampling analyses at suspect dioxin sites for local government and industry.

Fred C. Hart Associates specific dioxin work is backed up by a broad scientific base of expertise in dealing with hazardous waste management, risk assessment and public health:

- FCHA has a long history of investigations at hazardous waste disposal and treatment facilities. The firm has worked for nearly all of the major hazardous waste treatment companies and has represented local government as well.

- FCHA has conducted risk assessments for applicants for environmental impairment liability (EIL) insurance coverage. Our firm has relationships with a number of insurance companies including American Insurance Group, Aetna, and Hartford.

- For Aetna Life and Casualty, FCHA developed an environmental audit manual for use by field engineering personnel to inspect facilities of prospective clients who are attempting to obtain EIL insurance. The manual provided guidance in conducting environmental audits and risk assessments.

- FCHA conducted a similar effort for St. Paul Insurance Company where we provided training for company personnel in site evaluations and risk assessments for closure and post-closure insurance for hazardous waste management facilities.

- FCHA has conducted a variety of studies that address the technical feasibility and environmental impact of resource recovery facilities including over a dozen such studies for the U.S. Environmental Protection Agency.

The principal investigators for this project included:

Dr. David Lipsky, manager of the Public Health Group at Fred C. Hart Associates. He served as the Field Investigation Team Leader (FITL) for the Region II Field Investigation Team (FIT) and has six years' experience in assessing the impact of chemical contaminants on human health and the environment. Dr. Lipsky supervised a multidisciplinary team of 23 engineers and scientists, who performed extensive site investigations in the New York, New Jersey area.

Dr. Lipsky supervised the investigations of over 204 hazardous waste sites, including 40 sites designated as top priority under Superfund. The investigation activities included air, water, soil, sediment, and biota monitoring and collection programs, hydrogeologic and geophysical studies, risk assessments and engineering studies in support of remedial action plans.

Dr. Lipsky promoted and supervised the use of state-of-the-art techniques for measuring the impacts of toxic emissions on biota and ambient air quality. He has supervised air pollution studies near sanitary landfills to measure and assess air impacts at the parts per billion level. Dr. Lipsky also acted as the Senior Public Health Specialist for the Region II FIT, assessing and interpreting all data with regard to public health and environmental impacts.

Dr. Lipsky holds a Ph.D. in Biochemistry from the State University of New York at Stony Brook.

Karl Boldt, a Senior Air Quality Engineer with Fred C. Hart Associates, has over 13 years of experience in air quality emission assessments and impact analyses from new and existing stationary emission sources. He has designed and implemented continuous emission test programs on fossil fuel power plants, a cogeneration plant, and a cement kiln burning hazardous waste as fuel. He also developed air quality assessments of hazardous waste treatment, storage and disposal facilities including incinerators, landfills, tanks, and a solid waste resource recovery plant. Several projects included air quality impact analyses using USEPA manual and computer modeling techniques.

Mr. Boldt received a B.S. agree in Mechanical Engineering from the University of Rhode Island. He is a member of the American Society of Mechanical Engineers and the Air Pollution Control Association.

Mary Manto is a public health specialist and Assistant Project Manager for Fred C. Hart Associates. Her background is in toxicology, epidemiology, and safety planning. Since joining Fred C. Hart Associates, Ms. Manto's work has been mainly focused on the hazardous waste area. In the last five years she has participated in a variety of waste-related efforts including an assessment of the health risks posed by the development of a former hazardous waste site as a recreation area, and participation in a nationwide assessment of hazardous waste sites for Environmental Protection Agency Headquarters. Under this contract, Ms. Manto was responsible for health assessments concerning sites located in different areas of the country. These assessments involved preliminary epidemiological survey designs, health interviews, and toxicological research.

Ms. Manto holds an M.P.H. degree in environmental health from Columbia University.

Renee R. Bobal is an Assistant Project Manager and Chemist. Her responsibilities with the firm's New York office include conducting risk assessments and environmental impact analyses for government and private industry. She has developed an extensive management plan for the handling, storage, use, and disposal of hazardous materials for a multi-project industrial operation. She has managed a politically sensitive project concerning potential contamination of groundwater, soil, and air, which included risk assessment of past facility operations, developing and coordinating an environmental monitoring program, and assisting in the development of engineering controls for a proposed facility to alleviate potential impacts.

Ms. Bobal received her Bachelor and Master of Science degrees from Rutgers University.

Appendix 10.17

NEW JERSEY DEPARTMENT
OF ENVIRONMENTAL PROTECTION
DIVISION OF WASTE MANAGEMENT

RE: Public Hearing to Solicit :
and Receive Comment on the
Tentative Approval of Plans :
Submitted by the Applicant:
:
The American Ref-Fuel Company
of Essex County. :

TRANSCRIPT OF
PROCEEDINGS

Essex County Community College
University Avenue
Newark, New Jersey
Monday, December 17, 1984
2:00 p.m.

BEFORE:

ALBERT MONTAGUE,
Deputy Assistant Director, Engineering, Permits and Licensing of the Division of Waste Management

WILLIAM O'SULLIVAN,
CHIEF, Engineering and Technology of the Division of Environmental Quality

BARBARA GREER,
Assistant Director, Office of Regulatory Services, Department of Environmental Protection

DR. MARWAN SADAT,
Director of Division of Waste Management of the DEP

EDWARD POST,
Chief, Industrial Permits Section, Division of Water Resources

Reported by:
HELEN DOHOGNE, C.S.R.

(CONTINUED)

DR. RICHARD DIME,
Research Scientist, Bureau of Environmental Evaluation and Risk Assessment, Hazardous Site Mitigation Administration

DR. JOSEPH SPATOLA,
Director, Essex County Office of Environmental Health

MR. ROBERT GOLDEN,
Karch and Associates,
Washington, D.C.

WILBERT O'CONNELL,
Battelle Memorial Institute

ROBERT ENGDAHL,
Battelle Memorial Institute

opinion must make every effort to educate the American public and, in this case, New Jersey public, to the assets of resource recovery.

The safety, economy and ability to ensure a safe environment for our children and their children to follow makes it a mandate and our responsibility.

Resource recovery is today's path and tomorrow's path.

Yet it's something that's taken for granted as old hat all over Europe. I'm here today to support this technology that's so desperately needed by not only our sister county, Essex County, but Union County, Bergen County and all of the other counties and throughout our entire state and I speak on behalf the permit. Thank you.

DR. SADAT: Thank you very much. Mr. Gary Smith will represent the United States Environmental Protection Agency and will give a statement for Administrator Ruckelshaus.

MR. SMITH: Thank you, Dr. Sadat. The first thing I need to do is put my glasses on.

My name is Gary Smith. I am with the Solid Waste Branch of Region Two of the United States Environmental Protection Agency. And I am here today to deliver a statement from our administrator, Mr. William Ruckelshaus.

It is a pleasure to appear today to provide comments from the U.S. Environmental Protection Agency on the preconstruction permits for the Essex County Resource Recovery facility.

One of the most intransigent problems of any modern society, particularly one as prosperous as our own, is what to do with the discards of our prosperity.

This nation has a first class solid waste problem, both in terms of hazardous materials and the more mundane things each of us throws away every day, municipal trash. It is not confined to this county, to Essex County.

America's municipal waste stream is expanding at a rate of approximately four percent annually. Our trash is expensive to collect and it's getting more so.

It's difficult to segregate in any orderly fashion and some would say it's impossible to dispose of, at least conveniently.

Most cities are running out of places to dump it.

Our existing landfill capacity is

dwindling. And our citizens are increasingly reluctant to allow new disposal sites to be located anywhere near them.

Nothing seems to mobilize a community faster than the rumor that a new landfill is being planned nearby. At EPA, we refer to this as the NIMBY syndrome, people understand that wastes must be disposed of somewhere but not in my backyard.

It is this public opposition to the siting of new waste disposal facilities, based frequently upon fear as much as fact, that presents many cities and counties with the prospects of gridlock in the management of the thousands of tons of municipal wastes generated every day.

The public is justified in being fearful of unsound waste management practices. We have experience in dealing with the consequences of past mismanagement in our Superfund Program, and I can assure you that this is a very difficult problem to manage due to the complexity of these sites, in combination with the pitched emotions associated with environmental contamination.

During the past fifteen years, we have learned a great deal about our environment and the need to keep it clean and safer. Since the start of

EPA in 1970, our mission was simple: Protect our air and water resources from the materials we were haphazardly dumping into them.

As we succeeded in cleaning up these most obvious media, we discovered a new link in the environmental chain. Our lands and subsurface water supplies were at risk due to the disposal of increasing quantities of sludges, residues and other emissions generated during our environmental protection efforts.

Today, we know better. We are aware of the potential hazards associated with land disposal of wastes, both toxic and municipal. While landfilling continues to be the management technique of choice in many places, due largely to economic considerations, the tables are slowly turning.

I am confident that we will see dramatic changes in the years ahead, and we will move away from land disposal.

I submit that a variety of approaches must be explored as alternatives to landfilling. These innovative techniques will cost more, but, after all, we are an industrial nation. We benefit from the production of highly sophisticated consumer products.

Our standard of living is such that we can afford to manage our wastes in a manner that is as environmentally sound as possible. One of the most promising ways for managing the mountains of municipal waste generated daily in this nation is resource recovery. There is something inherently sensible in utilizing all of our resources to the fullest extent possible, whether they be virgin materials or recycleable wastes.

America has a reputation of being a disposable society -- conspicuously wasteful. This is an ironic circumstance for a nation also known for its productive efficiency and belief in the profit motive.

Management of waste is truly one of the leading challenges of our modern society. We know the old ways -- dumping wastes in and on the land -- don't work.

I am hopeful that resource recovery presents us with an opportunity to deal with wastes in a positive and responsible way.

Our challenges are many in resource recovery. We must overcome the inertia which resists all change. We must educate the public to the positive attributes of resource recovery and we must make these projects succeed through careful design and skillful operation. I think we can meet these challenges.

We at EPA believe that resource recovery presents the best available management option for dealing with the ever increasing volume of municipal solid waste. Through resource recovery, we cannot only reduce the size of the waste stream, we can also recover valuable energy and materials which otherwise would be lost.

Well designed and operated facilities that generate energy represent the state of the art in waste management. They are techically, environmentally, and economically sound alternatives to what we already know is a fundamentally shortsight

and unsound practice -- land disposal.

Bear in mind that this management option, like all other, is not free of risk. But the risks are manageable.

Today, more than fifty resource recovery systems are in place and operating throughout the United States; more than 20 others are on the way.

I am convinced that this is the way to go. These facilities enlarge our pooling of waste management options. If they meet our expectations, they will help to sway other communities that resource recovery may be for them as well.

If so, the message is coming none too soon. The mountain of waste is getting higher every day. Thank you.

DR. SADAT: Thank you, Mr. Smith.

Now, do we have any other public officials in the audience? We've taken public officials first. I believe I have a Mayor Leopold from Livingston. I guess he'll be coming later.

I have a letter which I am going to read into the record and it is a letter from Mr. Gerald A. Calabrese who is a Freeholder Director in Bergen County. It is addressed to Dr. Marwan Sadat, Director of Waste Management, New Jersey Department of Environmental Protection, 32 East Hanover Street, CN027, Trenton, New Jersey, 08625. Reference December 17, 1984 Public Hearing - Essex County Resource Recovery Facility.

"Dear Dr. Sadat:

"Because of the importance of the resource recovery subject, for the well-being of the residents of New Jersey, I requested the following statement be read at the public hearing and incorporated into the official hearing record.

APPendix 10.18

RECEIVED
AUG 11 1983
HAZEN & SAWYER, P.C.
Hollywood, Fla.

FLORIDA DEPARTMENT OF STATE
George Firestone
Secretary of State
DIVISION OF ARCHIVES,
HISTORY AND RECORDS MANAGEMENT
The Capitol, Tallahassee, Florida 32301
(904) 488-1480

July 22, 1983

In Reply Refer to:

Louis D. Tesar
Historic Preservationist
(904) 487-2333

Mr. Rhodes Robinson, Vice President
Coastal Zone Resources, Inc.
1001 U.S. Highway 1, Suite 305
Jupiter, Florida 33458

RE: Your Letter of June 28, 1983
Cultural Resource Assessment Request
Proposed Development of Two Resource Recovery Facilities and
Associated Landfills, Broward County, Florida

Dear Mr. Robinson:

In accordance with the procedures contained in 36 C.F.R., Part 800 ("Procedures for the Protection of Historic and Cultural Properties"), we have reviewed the above referenced project for possible impact to archaeological and historical sites or properties listed, or eligible for listing, in the National Register of Historic Places. The authorities for these procedures are the National Historic Preservation Act of 1966 (Public Law 89-665) as amended by P.L. 91-243, P.L. 93-54, P.L. 94-422, P.L. 94-458 and P.L. 96-515, and Presidential Executive Order 11593 ("Protection and Enhancement of the Cultural Environment").

A review of the Florida Master Site File indicates that no archaeological or historical sites are recorded for the project area. Furthermore, because of the location of the project, it is considered highly unlikely that any significant, unrecorded sites exist in the vicinity. Therefore, it is the opinion of this office that the proposed project will have no effect on any sites listed, or eligible for listing, in the National Register of Historic Places, or otherwise of national, state or local significance.

If you have any questions concerning our comments, please do not hesitate to contact us.

Your interest and cooperation in helping to protect Florida's archaeological and historical resources are appreciated.

Sincerely,

George W. Percy
State Historic
Preservation Officer

GWP:Teb

CZR, INCORPORATED
Coastal Zone Resources

1001 US HIGHWAY 1
SUITE 305
JUPITER, FL 33458

305/747-7455

June 28, 1983
→ July 6, arrived

Mr. George W. Percy
Deputy State Historic Preservation Officer
Division of Archives History and
Records Management
Florida Department of State
Tallahassee, FL 32301

Dear Mr. Percy:

CZR is working for Hazen and Sawyer, P.C., and Broward County in the development of two resource recovery facilities and associated landfills. Locator maps of the two areas are enclosed. I would appreciate your department's review of both sites for any known historic or archaeological resources. I would also appreciate any data relative to probability of resource occurrence and need to conduct an archaeological survey in both areas.

Should you have any questions, please feel free to call me at your convenience.

Sincerely yours,

Rhodes Robinson

Rhodes Robinson
Vice President

RR/jt

Attachments

no sites, no site likely A-95 no number project

Appendix 10.19

BROWN, WOOD, IVEY, MITCHELL & PETTY

ONE WORLD TRADE CENTER, NEW YORK, N.Y. 10048

212-839-5300

TELEX: 127324
CABLE ADDRESS. BROWOODLAW
TELECOPIER: 212-839-5599

555 CALIFORNIA STREET
SAN FRANCISCO, CA. 94104
TELEPHONE: 415-398-3909
TELECOPIER: 415-397-4621

ONE FARRAGUT SQUARE SOUTH
WASHINGTON, D. C. 20006
TELEPHONE: 202-383-7400
TELECOPIER: 202-383-7408

March 18, 1985

Mr. Ron Mills
Malcolm Pirnie, Inc.
2 Corporate Park Drive
Box 751
White Plains, New York 10602

Re: Broward County, Florida
<u>Resource Recovery Project</u>

Dear Mr. Mills:

Enclosed please find the Power of Attorney appointments on behalf of North Broward County Resource Recovery Project, Inc. and South Broward County Resource Recovery Project, Inc. Thomas Henderson requested that I send these forms to you.

If I can be of further assistance, please contact me (212-839-5398).

Sincerely,

Andrea Feirstein

Andrea Feirstein

AF:ms
Enclosure

POWER OF ATTORNEY

KNOW ALL MEN BY THESE PRESENTS, That

NORTH BROWARD COUNTY RESOURCE RECOVERY PROJECT, INC., a corporation organized and existing under the laws of Florida (hereinafter the "Corporation"), has irrevocably constituted and appointed, and by these presents does irrevocably constitute and appoint Thomas Henderson its true and lawful Attorney-in-Fact, with full power of substitution, with respect to all matters arising in connection with the development, acquistion, construction and operation of the proposed resource recovery facilities, financed by the issuance by Broward County, Florida of its Resource Recovery Revenue Bonds, Series 1984A, 1984B and 1984C. Without in any way limiting the generality of the foregoing, the power and authority of the said Attorney-in-Fact and of any substitute Attorney-in-Fact appointed hereunder, shall include the power and authority to make application for, execute and deliver on behalf of the Corporation any and all regulatory forms, permits and licenses as may be required by federal, state and local statutes, ordinances and/or administrative regulations, and any and all other agreements, contracts, consents and documents in connection with the Corporation's acting as aforesaid which the said Attorney-in-Fact or any such substitute Attorney-in-Fact may deem advisable. The Corporation hereby ratifies and confirms all that the said Attorney-in-Fact or any such substitute Attorney-in-Fact may do by virtue hereof.

IN WITNESS WHEREOF, the Corporation has caused these presents to be executed in its name a member of its Board of Directors this 18th day of March, 1985.

NORTH BROWARD COUNTY RESOURCE
RECOVERY PROJECT, INC.

By James B. May
James B. May
A member of the Board of Directors

POWER OF ATTORNEY

KNOW ALL MEN BY THESE PRESENTS, That

SOUTH BROWARD COUNTY RESOURCE RECOVERY PROJECT, INC., a corporation organized and existing under the laws of Florida (hereinafter the "Corporation"), has irrevocably constituted and appointed, and by these presents does irrevocably constitute and appoint Thomas Henderson its true and lawful Attorney-in-Fact, with full power of substitution, with respect to all matters arising in connection with the development, acquistion, construction and operation of the proposed resource recovery facilities, financed by the issuance by Broward County, Florida of its Resource Recovery Revenue Bonds, Series 1984A, Series 1984B and Series 1984C. Without in any way limiting the generality of the foregoing, the power and authority of the said Attorney-in-Fact and of any substitute Attorney-in-Fact appointed hereunder, shall include the power and authority to make application for, execute and deliver on behalf of the Corporation any and all regulatory forms, permits and licenses as may be required by federal, state and local statutes, ordinances and/or administrative regulations, and any and all other agreements, contracts, consents and documents in connection with the Corporation's acting as aforesaid which the said Attorney-in-Fact or any such substitute Attorney-in-Fact may deem advisable. The Corporation hereby ratifies and confirms all that the said Attorney-in-Fact or any such substitute Attorney-in-Fact may do by virtue hereof.

IN WITNESS WHEREOF, the Corporation has caused these presents to be executed in its name by a member of its Board of Directors this 18th day of March, 1985.

SOUTH BROWARD COUNTY RESOURCE
RECOVERY PROJECT, INC.

By Andrea K. Feirste
Andrea K. Feirstein
A member of the Board of Directors