PALM BEACH COUNTY
SOLID WASTE AUTHORITY

November 5, 1985

Florida Department of
Environmental Regulation
Twin Towers Office Building
2600 Blair Stone Road
Tallahassee, FL 32301-8241

Attn: Mr. Hamilton S. Oven, Jr., P.E.
Administrator
Siting Coordination Section

Re: Response to August 27, 1985 Letter
Application for Power Plant Site Certification
Resource Recovery Facility
Solid Waste Authority
Palm Beach County, Florida

Dear Mr. Oven:

Accompanying this letter are 45 copies of the response to your letter of August 27, 1985 in which (1) ten questions/comments from the Department of Environmental Regulation's Bureau of Air Quality Management and (2) comments from the U.S. Department of the Interior National Park Service concerning the application were included.

Responses to all of the questions/comments concerning the application are included in each response booklet for distribution. Responses to the Bureau of Air Quality Management questions 1 through 3 are under Tab No. 1, questions 4 through 6 are under Tab No. 2 and questions 7 through 10 are under Tab No. 3. The response to the comments from the National Park Service is under Tab No. 4. References B, C and D accompanying the responses are under Tab No. 5, 6 and 7 respectively.

Should you have any further questions please contact our office.

Very truly yours,

Thomas R. Keith
Environmental Compliance
Administrator

TRK/pc
enclosure

5114 Okeechobee Blvd. / Suite 2C / West Palm Beach, Florida 33409 / Telephone (305) 471-5770

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

RECEIVED
AUG 29 1985

August 27, 1985

Mr. Tim Hunt, Jr.
Executive Director
Palm Beach County Solid
Waste Authority
5114 Okeechobee Blvd.
Suite 2C
West Palm Beach, FL 33409

RE: Palm Beach County Resource Recovery Facility
PA 84-20

Dear Mr. Hunt:

Please respond to the attached comments from the department's Bureau of Air Quality Management concerning sufficiency of the certification application. Also you may wish to review the enclosed letter from the National Park Service.

Sincerely,

Hamilton S. Oven, Jr.
Hamilton S. Oven, Jr., P.E.
Administrator
Siting Coordination Section

HSOjr/sb

Attachment

cc: William Kendrick
All Parties
Don White

State of Florida
DEPARTMENT OF ENVIRONMENTAL REGULATION

INTEROFFICE MEMORANDUM

For Routing To District Offices
An To Other Than The Addressee

To: ______________ Loctn.: ______________
To: ______________ Loctn.: ______________
To: ______________ Loctn.: ______________
From: ______________ Date: ______________
Reply Optional [ ] Reply Required [ ] Info. Only [ ]
Date Due: ______ Date Due: ______

TO: Hamilton Oven

FROM: Clair Fancy

DATE: August 23, 1985

SUBJ: Palm Beach County Resource Recovery Facility - Sufficiency Review

Listed below are questions my staff has prepared to be submitted to the applicant. These questions need to be answered before final review of the application can be completed.

1. Submit a copy of the appropriate sections of the references used to devise the emission factors for all the pollutants emitted by the proposed facility.

2. Provide documentation that an electrostatic precipitator (ESP) will remove 99% of sulfuric acid mist at an exit gas temperature of 450 °F.

3. The emission factor for dioxins appears to be based on the emission factor for the Brooklyn Navy Yard project which will use a dry scrubber and baghouse for control. What is the emission factor when an ESP is used as the only control device.

4. Wet scrubbers were not evaluated in the BACT because they produced an "aesthetically undesirable water vapor plume." Provide all the appropriate evaluations of wet scrubbers for the proposed BACT.

5. The proposed BACT compares an ESP to a dryscrubber and baghouse. This is not a valid comparison. Submit the necessary data comparing a baghouse to an ESP and a dryscrubber with a baghouse to scrubber with an ESP.

6. A BACT economic analysis which evaluates unit cost per ton of pollutant removed should include all the pollutants; for example, dry scrubbers should address acids, SO_2 etc. Resubmit the economic data for all of the control systems which are to be evaluated.

7. Will any hospital waste or "red bag" waste be incinerated at this facility. If so, please quantify the amounts, composition, and the source of these materials.

8. Verify and correct, if necessary, the tons per year emissions contained in the air permit application.

9. Tables 5-9 A through F of appendix 10.1.5 contain results of the highest, second high modeled concentrations for the proposed facility. These results include values at a distance of 730 meters from the center of the facility. The modeled runs, however, do not include any receptors at this distance. Please explain.

10. EPA informed us very recently that The Power Plant Act is not totally compatable with their rules and they are going to rescind our delegation of sources subject to PSD PPS. The county needs to be informed of such and they must send a letter to me requesting that we perform the Technical and Administrative review for EPA so that they can issue a federal PSD permit.

TR/ks

United States Department of the Interior

NATIONAL PARK SERVICE
SOUTHEAST REGIONAL OFFICE
75 Spring Street, S.W.
Atlanta, Georgia 30303

IN REPLY REFER TO:

N3615(SER-OPS)

AUG 16 1985

Mr. Tom Rogers
Bureau of Air Quality Management
State of Florida
Department of Environmental Regulation
Twin Towers Office Building
2600 Blair Stone Road
Tallahassee, Florida 32301-8241

Dear Mr. Rogers:

Thank you for sending us a copy of the Palm Beach County Resource Recovery power plant site certification application for a proposed resource recovery facility in Palm Beach County, Florida, approximately 120 km northeast of Everglades National Park. Your early notification of this project is appreciated.

We have reviewed the information you sent to us and, based on that information, we would not expect emissions from the proposed facility to adversely impact the air quality or air quality values of Everglades National Park.

However, we have several comments regarding the air quality and control technology analyses contained in the application. These comments are discussed in the enclosed technical review document. We ask that you consider these comments while performing your review of the application. We also ask that you forward us a copy of your preliminary determination document once your technical review of the project is completed. We will review your preliminary determination and submit any additional comments regarding the project during the 30-day public comment period.

If you have any questions regarding the enclosed comments, please contact Mark Scruggs of our Air Quality Division in Denver at (303) 236-8765.

Sincerely,

Regional Director
Southeast Region

Enclosure

DER
AUG 22 1985
BAQM

Technical Review of Power Plant Site Certification Application for Palm Beach County Solid Waste Authority

By

Permit Review and Technical Support Branch
Air Quality Division - Denver

Palm Beach County Solid Waste Authority (Palm Beach County) is proposing to construct a resource recovery facility in an unincorporated section of Palm Beach County. The location is approximately 120 km northeast of Everglades National Park, a PSD class I area administered by the National Park Service. The purpose of the facility is to dispose of solid waste generated in Palm Beach County. The project will be a mass-burn facility with a maximum continuous design rated capacity of 3,000 tons per day of solid waste and a maximum electrical generating capacity of approximately 75 megawatts. The initial design is for 2,000 tons per day capacity and 50 megawatt generating capacity. The emissions from the proposed facility are estimated as follows based on 1,800 tons per day (annual average) of refuse burned: 3,942 tons per year (TPY) of carbon monoxide, 1,314 TPY of nitrogen oxides, 2,957 TPY of sulfur dioxide, 1,150 TPY of chlorides, 65.6 TPY of volatile organic compounds, 214 TPY of particulate matter, 0.131 TPY of sulfuric acid mist, 13.2 TPY of fluorides, 0.46 TPY of lead, 0.98 TPY of mercury, and 0.003 TPY of beryllium.

Under the PSD regulations, these emission rates are considered significant for carbon monoxide, nitrogen oxides, sulfur dioxide, volatile organic compounds, fluorides, mercury, beryllium, and particulate matter. Therefore, new source review is required for the aforementioned pollutants. Following are our comments on the best available control technology, air quality, and air quality related values analyses with respect to ~~the~~ project's expected impacts.

BEST AVAILABLE CONTROL TECHNOLOGY ANALYSIS

The major sources of emissions at the proposed facility are the three associated boilers. Therefore, our review will focus on emission controls on these units. Also, there is a relatively recent publication entitled, "Air Pollution Control at Resource Recovery Facilities" that discusses resource recovery facilities in detail. This document was published in May 1984 by the California Air Resources Board, and was summarized in a technical paper presented at the 77th annual meeting of the Air Pollution Control Association held in June 1984. As of 1984, all refuse-burning facilities with applications pending in California are proposing control technologies that are consistent with, or more stringent than, the guideline emission limits discussed in this report. We refer to this publication throughout our comments on the proposed air pollution control technology analysis.

Particulate Matter (PM)

Palm Beach County proposes to use electrostatic precipitators (ESPs) to minimize PM emissions generated by combustion of the solid waste in the boilers. Each ESP will be capable of reducing the exhaust gas PM concentration to 0.03 grains per dry standard cubic foot (gr/dscf). Palm Beach County states that an ESP with an outlet grain loading of 0.03 gr/dscf is best available control technology (BACT) for the proposed facility.

We agree that high efficiency control devices such as ESPs or baghouses represent BACT for PM emissions from the proposed facility. However, based on information provided in the California Air Resources Board (CARB) document referenced above, an emission limit of 0.01 gr/dscf can be achieved with these devices. This is the guideline emission limit proposed by the CARB for new refuse recovery facilities in California and should be considered as the BACT emission limit.

Palm Beach County indicates on page 8, Volume IV, of their certification application that they could obtain a guaranteed PM emission rate of less than 0.01 gr/dscf from a baghouse. However, they determined a baghouse was not appropriate due to filter media blinding and due to the incidence of fires caused by sparks.

Baghouses have been installed at several refuse burning facilities. Blinding problems were encountered at the East Bridgewater, Massachusetts, installation, but the unit was rebuilt to maintain flue gas temperature at 500°F through the baghouse. The modification apparently solved the major blinding problems. If baghouses are installed, and if the proposed flue gas temperature is increased from 450°F to 500°F, blinding should not be a major problem. The spark carry over and danger of fire in the bags could be minimized by installing a primary collector such as a multitube cyclone ahead of the baghouse. Regardless of whether baghouses or ESPs are installed we feel an emission limit of 0.01 gr/dscf represents BACT.

Sulfur Dioxide (SO_2)

Palm Beach County is proposing no control devices for limiting SO_2 emissions; rather, they are proposing the firing of low sulfur refuse as BACT for the proposed facility. The resulting BACT limit proposed is 0.7 pounds per million Btu heat input ($lb/10^6$ Btu).

The emission guideline recommended in the CARB document is 30 ppm, which corresponds to an SO_2 emission rate of approximately 0.08 $lb/10^6$ Btu. To achieve this emission level, flue gas controls such as wet or dry scrubbing are required. Dry scrubbing processes have been effectively employed at pilot and full-scale refuse burning facilities in Europe, Japan, and the United States. Wet scrubbers have also been employed at full-scale refuse burning facilities. In light of this information, we recommend that Palm Beach County re-evaluate flue gas scrubbing as BACT for SO_2 emissions from the proposed facility.

Nitrogen Oxide (NO_x) and Carbon Monoxide (CO)

The proposed BACT for NO_x and CO emissions is boiler design and good combustion practices. The resulting NO_x and CO emissions limits proposed are 0.3 and 1.0 $lb/10^6$ Btu, respectively. Based on information presented in the CARB report, combustion modifications such as staged combustion, low excess air, and flue gas recirculation can reduce NO_x emissions to between 140 to 200 ppm or 0.28 to 0.4 $lb/10^6$ Btu. Since the proposed NO_x limit falls in this range, we agree that the proposed combustion controls and corresponding emission limit represent NO_x BACT. Regarding CO emissions, proper application of the above combustion modification techniques will also minimize CO emissions.

Other Pollutants

Other pollutants emitted from the proposed resource recovery facility requiring BACT review include fluoride, beryllium, and mercury. The proposed BACT for beryllium is the ESPs for the control of particulate matter emissions. Beryllium is emitted in the solid phase, therefore control of PM emissions will also control beryllium emissions. We agree that the proposed ESPs represent BACT for beryllium.

Fluorides and mercury are emitted in small quantities primarily in the gaseous phase. No additional controls are proposed for these pollutants. However, if the wet or dry scrubbers recommended for SO_2 control were installed, the fluoride emissions could be reduced by over 90 percent.

Our last comment in this section pertains to the large discrepancies in some of Palm Beach County's emission estimates compared to those made for the Broward County refuse recovery facility in their March 1985 site certification application. Since the Palm Beach County facility is rated (annual average) at 1,800 tons per day (initial stage) and the Broward County facility is rated at 3,300 tons per day, we would expect the ratio of the Palm Beach County to Broward County emissions to be 1800/3300 or 0.55.

The following table illustrates that, for several pollutants, this is not the case:

Pollutant	Emission Rate for Palm Beach County (Tons Per Year)	Emission Rate for Broward County (Tons Per Year)	Palm Beach C Broward Co. Ratio
SO_2	2957	3428	0.86
NO_x	1314	3491	0.38
CO	3942	555	7.10
PM	214	461	0.46
Lead	0.46	187	0.002
Fluorides	13.2	156	0.085
Sulfuric Acid Mist	0.131	17.3	0.008

The above inconsistencies in emission estimates should be resolved before granting power plant site certifications for the proposed facilities.

AIR QUALITY ANALYSIS

The air quality modeling analysis appears to be adequate for the study area that was analyzed. However, there is no indication of estimates of concentration values in Everglades National Park, a class I area. A screening level air quality modeling analysis should have been performed. Also, at a minimum, a Level I visibility analysis should be done and the results given. (Note: Due to the lack of such a technical analysis, we performed a Level I visibility analysis. Based on the expected emissions and the distance to the park, the analysis confirms that the project should not significantly impact the visibility at Everglades National Park).

AIR QUALITY RELATED VALUES ANALYSIS

Presently, low SO_2 concentrations have been monitored in Everglades National Park, and the proposed project would probably contribute little to the concentrations. Therefore, we do not anticipate any adverse impacts on air quality related values (AQRVs) in the park from SO_2. However, because this appears to be a high-growth area, and because bioassays of lichens and epiphytes in the park are showing elevated levels of sulfur, we would like to see a cumulative modeling analysis showing the pollutant concentrations expected at Everglades National Park from the proposed source, background, and all other proposed sources.

In addition, high ozone levels have been monitored in Everglades National Park, and we have commenced studies to determine if there are any adverse impacts on vegetation. However, we do not expect the proposed source to significantly contribute to ozone levels in the park. However, it is known that for some species small amounts of SO_2 can act synergistically with the ozone to cause more foliar injury than would be expected with the SO_2 or ozone alone. We are awaiting results of fumigation studies being conducted for us by EPA on slash pine using O_3 and SO_2 which will give us information on how much SO_2 can be added to high O_3 areas before impacts on slash pine will occur.

CONCLUSION

Based on the information provided, we would not expect emissions from the proposed facility to adveresly impact the air quality or air quality related values of Everglades National Park. However, we have made several comments regarding the proposed control technology and air quality analyses that should be addressed before the power plant site certification is granted for the proposed project. Results from current studies may lead to the National Park Service reaching different conclusions about the effects of similar sources on AQRVs in the future.

October 18, 1985

PALM BEACH COUNTY SOLID WASTE AUTHORITY

SUPPLEMENTAL REPORT

IN RESPONSE TO

STATE OF FLORIDA

DEPARTMENT OF ENVIRONMENTAL REGULATION

SUFFICIENCY REVIEW

OF

AIR QUALITY IMPACTS ANALYSIS

FOR PROPOSED

PALM BEACH COUNTY SOLID WASTE AUTHORITY

SOLID WASTE-TO-ENERGY FACILITY

PREFACE

This Supplemental Report is in response to State of Florida Department of Environmental Regulation (DER) communication of August 27, 1985 (from Hamilton S. Oven, Jr., P.E., Administrator, Siting Coordination Section to Tim Hunt, Jr., Executive Director, Palm Beach County Solid Waste).

The DER communication included a Sufficiency Review by DER staff embodied in a two-page Interoffice Memorandum listing ten questions (from Clair Fancy to Hamilton Oven) dated August 23, 1985 and also a four-page Technical Review of the Authority's Power Plant Site Certification Application. The Technical Review was authored by the U.S. Department of the Interior National Park Service Southeast Regional office, transmitted by National Park Service August 16, 1985 letter directed to Mr. Tom Rogers, Bureau of Air Quality Management of the DER.

The response to questions raised by DER and the National Park Service is provided in four sections of this Supplemental Report as follows:

Section I - addresses Questions 1,2 and 3 of DER August 23, 1985 Interoffice Memorandum on the subject of Emission Factors.

Section II - responds to DER August 23, 1985 Interoffice Memorandum Questions 4, 5 and 6 on the issues of Best Available Control Technology (BACT) and addresses comments by National Park Service on this subject.

Section III - covers the Authority's response to DER Questions 7, 8, 9 and 10 on miscellaneous matters encompassing hospital waste, annual emissions, air quality modeling receptors and Technical and Administrative review protocol, respectively.

Section IV - responds specifically to the issues raised in the National Park Service Technical Review.

An Appendix section is included, reproducing in entirety References B, C and D used in Section I development of emission factors. These reference documents may not be readily available to DER and are included in the Appendix to facilitate the DER review by providing complete contexts to the exhibited excerpts taken from the documents for development of specific emission factors.

SECTION I

EMISSION FACTORS

SECTION I

EMISSION FACTORS

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SECTION I

EMISSION FACTORS

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* For list of References, See pages I-1 & 2.

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* For List of References, see pages I-1 & 2.

PALM BEACH COUNTY SOLID WASTE AUTHORITY
SOLID WASTE - TO ENERGY FACILITY
REPORT ON AIR QUALITY IMPACTS ANALYSIS
RESPONSE TO FLORIDA DER SUFFICIENCY REVIEW

QUESTION NO. 1:

SUBMIT A COPY OF THE APPROPRIATE SECTIONS OF THE REFERENCES USED TO DEVISE THE EMISSION FACTORS FOR ALL THE POLLUTANTS EMITTED BY THE PROPOSED FACILITY.

RESPONSE:

LIST OF REFERENCES

A. "AIR POLLUTION CONTROL AT RESOURCES RECOVERY FACILITIES",

PRELIMINARY DRAFT,

CALIFORNIA AIR RESOURCES BOARD,

NOVEMBER 15, 1983

B. "EMISSIONS AND EMISSION CONTROL IN MODERN INCINERATORS",

W. L. O'CONNELL, G. C. STOTLER, AND R. CLARK,

BATTELLE'S COLUMBUS LABORATORY, COLUMBUS, OHIO

1982 ASME NATIONAL WASTE PROCESSING CONFERENCE PROCEEDINGS

C. "AN EVALUATION OF EMISSION FACTORS FOR WASTE - TO - ENERGY SYSTEMS" -

EXECUTIVE SUMMARY,

G. M. RINALDI, T. R. BLACKWOOD, D. L. HARRIS & K. M. TACKETT

MAY 29, 1979 USEPA CONTRACT NO. 68-03-2550, TASK II

D. "SUMMARY REPORT - ASSESSMENT OF NON-CRITERIA POLLUTANT EMISSIONS"
PREPARED FOR NORTH SANTA CLARA COUNTY SOLID WASTE AUTHORITY

BY HAYDEN-WEMAN/CARROLLO ENGINEERS

OCTOBER 25, 1983

E. FOSTER WHEELER ENERGY CORPORATION LETTER TO HAYDEN-WEGMAN, INC.

DECEMBER 6, 1984

F. VOLUME IV - AIR QUALITY REPORT, APPENDIX 10.1.5 ON PREVENTION OF

SIGNIFICANT DETERIORATION, PALM BEACH COUNTY, FLORIDA SOLID WASTE

RESOURCE RECOVERY FACILITY APPLICATION FOR POWER PLANT SITE

CERTIFICATION DATED APRIL, 1985

G. "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.

AUGUST 17, 1984.

PARAGRAPH NUMBERS PROVIDED BELOW ARE KEYED TO THE PARAGRAPH NUMBERS USED IN THE AUTHORITY INITIAL APPLICATION.

4.1.1 TOTAL SUSPENDED PARTICULATE (PM)

THE EMISSION FACTOR IS BASED UPON THE ABILITY OF THE ELECTROSTATIC PRECIPITATOR MANUFACTURER TO NOT EXCEED A GUARANTEED GRAIN LOADING OF 0.03 GRAINS/DSCF AT 12% CO2. THIS EMISSION LEVEL REPRESENTS BACT FOR TSP.

FROM REFERENCE "A", TABLE 29, (EXHIBIT 4-1) UNDER RDF-FIRED SPREADER STOKER TYPE,

UNCONTROLLED PM EMISSION IN GRAINS/DSCF, 12% CO_2
= 1.08 TO 3.52 = 2.30 (AVERAGE); % REMOVAL EFF. TO OBTAIN 0.03 GR/DSCF ASSUMING GRAIN LOADING OF 3.0 GR/DSCF = $100(1 - \frac{0.03}{3.00}) = 99\%$

UNCONTROLLED PM EMISSION IN LB/1.0E6 BTU
= 3.0 TO 7.4 = 5.2 (AVERAGE)
CONVERT LB/1.0E6 BTU TO LB/TON,
5.2 LB/1.0E6 X 6164 BTU/LB X 2000 LB/TON = 64.11 LB/TON

AFTER 99% REMOVAL BY ESP,
CONTROLLED PM EMISSION = 64.11 X (1 - .99)
= 0.6411 LB/TON
= 0.65 LB/TON (ROUNDED)

PM

Table 29

EXHIBIT 4-1

Uncontrolled Particulate Matter Emissions at Refuse-Burning Facilities

Type of Facility	Particulate Matter Emissions: Concentrations grams/Nm^3, dry† (grains/dscf) Low	High	Emission Rates grams/GJ†† (lb/10^6 Btu) Low	High
Mass Burning Refractory Wall	1.26 (0.55)	3.96 (1.73)	198 (0.46)	955 (2.22)
Mass Burning Waterwall	1.90 (0.83)	4.70 (2.05)	547 (1.27)	3150 (7.32)
RDF-Fired Spreader Stoker	2.47 (1.08)	8.06 (3.52)	1290 (3.0)	3180 (7.4)
Rotary Kiln	2.66 (1.16)	3.53 (1.54)	1080 (2.51)	1450 (3.37)

†Concentrations corrected to 12% CO_2 and are based on the front half of EPA Method 5 Sampling Train

††Rates based on HHV of refuse "as-fired"

Source: Appendix B

Concentration data listed in Table 29 are corrected to 12 percent CO_2 for comparative purposes. The concentration data indicate that uncontrolled particulate matter concentrations are highest at RDF-fired spreader stoker units and lowest at the refractory wall mass-burning units and rotary kilns. In addition, the concentration data show that wide variations exist within each class of facility.

Emission rate data follow a pattern similar to the one set by the concentration data. The RDF-fired spreader stoker units are the highest emitters of uncontrolled particulate matter. Uncontrolled particulate matter emission rates at these facilities range between approximately 1300 to 3200 grams per billion Joules (3.02 to 7.44 lbs per million Btu) of fuel (as-fired). Mass-burning waterwall units have slightly lower particulate matter emission rates, ranging from approximately 550 to 3200 grams per billion Joules (1.28

4.1.2 SULFUR DIOXIDE (SO2)

THE SO2 EMISSION FACTOR IS BASED UPON RDF FUEL SULFUR CONTENT WHICH IS ASSUMED TO BE COMPLETELY CONVERTED TO SO2.

FROM TABLE 1-2 ON PAGE 4 (EXHIBIT 4-2) IN *VOL. IV - AIR QUALITY REPORT, APPENDIX 10.1.5 ON PREVENTION OF SIGNIFICANT DETERIORATION,

SULFUR CONTENT IN RDF = 0.22 LB/100 LB RDF
= 4.4 LB/TON RDF

ASSUME 100% CONVERSION FROM S TO SO2,

$$S + O_2 \longrightarrow SO_2$$

MOL. WT. 32 64

THEREFORE,

4.4 LB S/TON = 8.8 LB SO2/TON
= 9.0 LB SO2/TON (ROUNDED)

---

*PALM BEACH COUNTY, FLORIDA SOLID WASTE RESOURCE RECOVERY FACILITY APPLICATION FOR POWER PLANT SITE CERTIFICATION DATED APRIL, 1985

EXHIBIT 4-2

HAYDEN-WEGMAN /
BARKER, OSHA & ANDERSON
ENGINEERS - PLANNERS

TABLE 1-2

PALM BEACH COUNTY SOLID WASTE COMPOSITION STUDY

TYPICAL ANALYSIS AND COMPOSITION OF REFUSE DERIVED FUEL (RDF)
PERCENT BY WEIGHT

COMPONENT	RECOVERY RATE (%)	MOISTURE	INORGANIC	CARBON	HYDROGEN	OXYGEN	NITROGEN	CHLORINE	SULFUR	TOTAL	HHV BTU/LB
CORRUGATED BOARD	99.0	1.48	0.17	2.72	0.38	2.62	0.01	0.01	0.02	7.39	461.
NEWSPAPER	99.0	5.10	0.37	8.76	1.11	7.60	0.03	0.03	0.04	23.03	1488.
MAGAZINES	99.0	0.78	0.62	1.55	0.22	1.54	0.01	0.01	0.01	4.72	260.
OTHER PAPER	99.0	5.78	2.39	8.56	1.19	7.90	0.08	0.16	0.05	26.12	1448.
PLASTICS	98.0	1.12	0.90	5.92	0.82	0.84	0.09	0.31	0.03	10.03	1215.
RUBBER, LEATHER	99.0	0.20	0.64	1.22	0.15	0.33	0.04	0.14	0.03	2.76	239.
WOOD	99.0	0.14	0.03	0.50	0.06	0.42	0.00	0.00	0.00	1.16	84.
TEXTILES	98.0	0.41	0.10	1.92	0.26	1.40	0.16	0.01	0.01	4.28	340.
YARD WASTE	85.0	0.50	0.13	0.30	0.04	0.22	0.01	0.00	0.00	1.19	51.
FOOD WASTE	60.0	0.69	0.29	1.04	0.15	0.74	0.07	0.02	0.00	3.01	189.
MIXED COMBUSTIBLES	40.0	3.70	0.77	2.21	0.31	1.75	0.05	0.04	0.02	8.85	386.
FERROUS	7.0	0.01	0.53	0.01	0.00	0.01	0.00	0.00	0.00	0.56	1.
ALUMINUM	35.0	0.01	0.88	0.01	0.00	0.01	0.00	0.00	0.00	0.93	2.
OTHER NON-FERROUS	10.0	0.00	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.05	0.
GLASS	35.0	0.08	5.78	0.03	0.00	0.02	0.00	0.00	0.00	5.92	5.
TOTALS		20.00	13.66	34.75	4.69	25.40	0.54	0.73	0.22	100.00	6171.

HEAT VALUE AS PRODUCED (20.0% H2O) = 6171.
HEAT VALUE OF DRY SOLIDS = 7714.
HEAT VALUE OF COMBUSTIBLES = 9302.

ASH AS PRODUCED (20.0% H2O) = 13.7%
DENSITY = 2.5 TO 3.5 POUNDS/CUBIC FOOT
SIZE = MINUS 2" X MINUS 2" X MINUS 2"

4.1.3 CARBON MONOXIDE (CO)

SEVERAL DATA BASES WERE INVESTIGATED TO DEVELOP AN EMISSION FACTOR FOR CO.

FROM REFERENCE "A", TABLE 34 (EXHIBIT 4-3.1) UNDER RDF-FIRED

SPREADER STOKER,

UNCONTROLLED CO EMISSION IN LB/1.0E6 BTU = .44 TO 2.3
CONVERT LB/1.0E6 BTU TO LB/TON,
.44 LB/1.0E6 BTU X 6164 BTU/LB X 2000 LB/TON = 5.43 LB/TON
2.3 LB/1.0E6 BTU X 6164 BTU/LB X 2000 LB/TON = 28.35 LB/TON

THEREFORE,
UNCONTROLLED CO EMISSION IN LB/TON = 5.43 TO 28.35

FROM REFERENCE "B", PAGE 290, TABLE 7 (EXHIBIT 4-3.2)

UNCONTROLLED CO EMISSION IN LB/TON = 1.9 LB/TON

FROM REFERENCE "E", (EXHIBIT 4-3.3 SHEETS 1&2)

UNCONTROLLED CO EMISSION IN PPM = 500 ----------------(1)
CONVERT FROM PPM TO LB/TON RDF BASED ON FOSTER WHEELER'S DATA,
500 CF OF CO = 500 CF X 28 LB/379 CF = 36.94 LB OF CO -----(2)
212,500 ACFM = 212,500 ACF/MIN X (460+60) R/(460+450) R
= 121,429 SCFM --------------------------------(3)
750 TPD=750 TPD X HR/60 MIN X DAY/24 HR = 0.5208 TON/MIN--(4)
(3)/(4) = 121,429 SCFM / 0.5208 TON/MIN = 233,159 SCF/TON RDF
1000000 SCF OF FLUE GAS = 1000000 SCF / 233,159 SCF/TON RDF
= 4.29 TON RDF -------------------(5)
(2)/(5) = 500 PPM = 36.94 LB CO / 4.29 TON RDF
= 8.61 LB CO/TON RDF

THE PRINCIPAL REASON FOR THE DIFFERENCE IN EMISSION FACTORS LISTED ABOVE IS DUE TO EXCESS AIR DESIGN. MOST OF THE SPREADER STOKER FURNACES CITED BY CARB WERE DESIGNED TO FIRE RDF AT ABOUT 40% EXCESS AIR. OUR INVESTIGATIONS HAVE INDICATED THAT A PRUDENT OPERATING POINT FOR RDF COMBUSTION TO BE AT 50% EXCESS AIR WITH A DESIGN POINT OF 60% TO ACCOMMODATE VARIATIONS IN FUEL MOISTURE AND HEATING VALUE. ACCORDINGLY A MEDIUM VALUE OF 12 LB/TON RDF IS SELECTED AS THE EMISSION FACTOR FOR CO.

CO/HC

EXHIBIT 4-3.1

Table 34

Uncontrolled Matter Emissions of CO and THC at Refuse-Burning Facilities*

Type of Facility	Concentrations (ppmv, dry)+					Emissions Rates grams/GJ ($lb/10^6$ Btu)			
	CO		THC**			CO		THC	
	Low	High	Low	High		Low	High	Low	High
Mass Burning Refractory Wall	87	99	84	169		26 (.06)	27 (.06)	14 (.03)	17.0 (.04)
Mass burning Waterwall	105	2186	7.3	60		65 (.15)	860 (2.0)	1.3 (.003)	1.7 (.004)
RDF-Fired Spreader Stoker	196	1160	8	2450		190 (.44)	1000 (2.3)	8.6 (.02)	470 (1.09)
Rotary Kiln	48	3500	NA	NA		14 (.03)	1100 (2.6)	NA	NA

+ Concentrations corrected to 12% CO_2

* Rates based on HHV of fuel "as-fired"

** THC reported as methane

NA Not Available

Source: Appendix B

EXHIBIT 4-3.2

TABLE 6 NITROGEN OXIDE EMISSIONS

Incinerator	lb/Ton	kg/Mg	actual ppm	ppm corr. to 12% CO_2	Ref.
Various	3.0	(1.5)			8
Various	1.6	(0.8)			1
Braintree			94		4
Nashville			106	160	29
Babylon			35.8	78	31
Babylon			28.9	64.6	28
Newport News			39	151	30
NW Brooklyn			61.3	156	30
Oceanside			104		30
Oberhausen				155	15
Various			6-177		6
Chicago NW			179		12
E Hamilton			112		12
Harrisburg	2.66	(1.33)			12
Harrisburg			123		3
Saugus	2.25	(1.12)			17
Average	2.30	(1.15)	88.7	129.4	
Std. Dev.	.52	(0.26)	57.1	41.6	

The nitrogen oxide emissions reported are quite variable. We feel that the Rinaldi [1] value of 1.6 lb/ton (0.8 kg/Mg) of refuse burned, which is equivalent to about 75 ppm in the flue gas, is a reasonable and conservative value for a modern waterwall incinerator.

CONTROLS

Since the NO_x levels are naturally comparatively low, the control of NO_x is not practiced on mass-burning municipal incinerators. Combustion modification techniques applicable to fossil fuel-fired-boilers either are generally not applicable to the mass-burning situation or tend to cause higher CO emissions and unacceptable boiler corrosion. One of the add-on control systems available for fossil fuel-fired-boilers has been tested in Japan [32]. The results of the test showed that the NO_x could be reduced by 60 percent by injecting NH_3 under precise control into the incinerator firebox. About 20 ppm of unreacted NH_3 remaining in the gas caused precipitates of ammonium salts to form in the economizer.

This test does not appear to establish that these reductions have been "achieved in practice" by a municipal incinerator as required in the regulations to establish LAER or BACT and thereafore should not be used to establish BACT or LAER.

CARBON MONOXIDE

EMISSIONS

Carbon monoxide is a product of incomplete combustion and for municipal incineration depends largely on the overfire air ratio, the design of the overfire air jets, and the combustion temperature. Values of CO reported in the literature are shown in Table 7. Considering these data, we have chosen a somewhat conservative 150 ppm as a reasonable estimate for a modern incinerator design using the combustion control measures now commonly used to control boiler tube wastage. This is equivalent to an emission rate of 1.9 lb/ton (0.95 kg/Mg) of refuse burned.

TABLE 7 CARBON MONOXIDE EMISSIONS

Incinerator	lb/Ton	kg/Mg	actual ppm	ppm corr. to 12% CO_2	Ref.
Various	35	(18)			8
Braintree			473*	1340	4
Nashville			153	176	29
Newport News			5.2-105		30
Various			6.1-179		6
Saugus	0.17	(0.08)			17
Average			103.3	758	
Std. Dev.			67.9	-	

* Incineration problems reported

CONTROLS

The CO emissions from modern incinerators are usually limited to a few hundred ppm by combustion control measures designed to achieve good combustion and minimize boiler tube wastage. The maintenance of a minimum temperature and adequate turbulence (usually by means of overfire air jets) in the firebox – as required to control flame length, insure complete combustion, and reduce the corrosion of the boiler tubes – normally provides adequate control of CO and no additional controls are required.

HYDROCARBONS

EMISSIONS

Hydrocarbons appearing in the flue gas of an incinerator are products of incomplete combustion. They are mostly low-molecular-weight hydrocarbons, aldehydes, and organic acids with traces of high molecular-weight compounds also present. Values reported for hydrocarbon emissions from municipal incinerators are shown in Table 8. Older refractory wall incinerators frequently have higher HC and CO emissions than modern waterwall incinerators. Considering these data, we have chosen an emission rate of 0.12 lb/ton (0.06 kg/Mg) which

EXHIBIT 4-3.3 (Sh. 1 of 2)

FOSTER WHEELER ENERGY CORPORATION
38 MEADOWLAND PARKWAY • SECAUCUS, N. J. 07094 • PHONE 201-864-9880 • (NYC) 212-564-5301

December 6, 1984

Hayden-Wegman, Inc.
330 West 42nd Street
New York, New York 10036

Attention: Mr. Louis A. Terracciano

Subject: Hayden-Wegman for
Palm Beach County, Florida
FWL Ref. 282-253

Dear Lou:

Please accept my apologies for the delay in getting the information you requested to you.

We have recalculated the data contained herein on the basis of two boilers each capable of handling 750 tons of RDF.

The following data applies for MCR, 75% load, and 50% load respectively.

	MCR	75%	50%
Fuel Qty. (pph)	62,187.5	46,227.5	30,597.5
Fuel HHV (Btu/lb.)	6,164	6,164	6,164
Excess Air (%)	80	80	80
Gas Exit Temp. (deg F)	450	430	410
ACFM	212,500	156,250	100,000
NO_x (ppm)	250	Note 1	
SO_x (ppm)	150	Note 2	
Particulate (lb./10 6 Btu)	0.1	Note 3	
CO (ppm)	500	Note 4	
HC (ppm)	70	Note 4	

Notes:

1. As load decreases, NO_x will decrease slightly. However, no data available to determine by how much.

EXHIBIT 4-3.3 (Sh. 2 of 2)

Notes (continued):

2. SO_x level will remain fairly constant as load decreases.

3. Particulate after precipitation will decrease slightly as load decreases but very slightly.

4. CO and HC emissions will increase slightly as load decreases. However, no data available to determine by how much.

I hope that this new data meets your needs. Should you have any questions, please do not hesitate to call me and, I assure you, we will be more prompt in answering these requests.

Sincerely,

FOSTER WHEELER ENERGY CORPORATION

Bill

William F. Bischoff
Assistant Regional Manager
Northeast Region

/lja

ccb: J.L. Van Buren
J.G. Foster
I.G. Lutes
D.A. Cassino
W. Murray
H.J. Schonhans
C.C. Robinson - FWL
H.M. Trammell, Jr. - Miami office

4.1.4 VOLATILE ORGANIC COMPOUNDS (VOC)

THE EMISSION FACTOR FOR VOC REPRESENTS THE NON-METHANE PORTION OF THE TOTAL HYDROCARBON EMISSIONS.

FROM REFERENCE "A", TABLE 34, PAGE (EXHIBIT 4-4.1) UNDER RDF-FIRED SPREADER STOKER TYPE,

UNCONTROLLED TOTAL HYDROCABBON EMISSION IN LB/1.0E6 BTU
= 0.02 TO 1.09

CONVERT LB/10E6 TO LB/TON,

.02 LB/1.0E6 BTU X 6164 BTU/LB X 2000 LB/TON = 0.25 LB/TON
1.09 LB/1.0E6 BTU X 6164 BTU/LB X 2000 LB/TON = 13.44/TON

THEREFORE,

UNCONTROLLED TOTAL HYDROCARBON EMISSION IN LB/TON
= 0.25 TO 13.44

FROM REFERENCE "B", PAGES 290 & 291 (EXHIBIT 4-4.2 SHEETS 1 & 2)

UNCONTROLLED TOTAL HYDROCARBON EMISSION IN LB/TON
= 0.12

FROM REFERENCE "C", TABLE 10, PAGE 8 (EXHIBIT 4.4.3)

UNCONTROLLED TOTAL HYDROCARBON EMISSION IN LB/TON
= 0.002 TO 0.01

REFERENCE LITERATURE INDICATED A WIDE RANGE OF VOC EMISSIONS. THIS WIDE RANGE IS BELIEVED TO BE CAUSED BY THE VARIATIONS IN EXCESS AIR DESIGN CITED IN DISCUSSION ABOVE FOR CO AND THE INABILITY TO MAINTAIN SUFFICIENT TEMPERATURE AND INADEQUATE COMBUSTION CONTROLS. THE PROPOSED FACILITY WILL UTILIZE STATE-OF-ART COMBUSTION CONTROLS COUPLED WITH CONSERVATIVE FURNACE DESIGN IN TERMS OF EXCESS AIR, GAS TEMPERATURE AND DWELL TIME TO MINIMIZE VOC EMISSIONS. ACCORDINGLY, THE VOC EMISSION FACTOR OF 0.20 LB/TON WAS SELECTED FROM MID-RANGE DATA TO PROVIDE SUFFICIENT CONSERVATISM AND AVOID UNDERSTATING POSSIBLE FACILITY EMISSIONS.

CO/HC

EXHIBIT 4-4.1

Table 34

Uncontrolled Matter Emissions of CO and THC at Refuse-Burning Facilities*

Type of Facility	Concentrations (ppmv, dry)+					Emissions Rates grams/GJ (lb/10^6 Btu)			
	CO		THC**			CO		THC	
	Low	High	Low	High		Low	High	Low	High
Mass Burning Refractory Wall	87	99	84	169		26 (.06)	27 (.06)	14 (.03)	17.0 (.04)
Mass burning Waterwall	105	2186	7.3	60		65 (.15)	860 (2.0)	1.3 (.003)	1.7 (.004)
RDF-Fired Spreader Stoker	196	1160	8	2450		190 (.44)	1000 (2.3)	8.6 (.02)	470 (1.09)
Rotary Kiln	48	3500	NA	NA		14 (.03)	1100 (2.6)	NA	NA

+ Concentrations corrected to 12% CO_2

* Rates based on HHV of fuel "as-fired"

** THC reported as methane

NA Not Available

Source: Appendix B

EXHIBIT 5-4.2 (Sh. 1 of 2)

TABLE 6 NITROGEN OXIDE EMISSIONS

Incinerator	lb/Ton	kg/Mg	actual ppm	ppm corr. to 12% CO2	Ref.
Various	3.0	(1.5)			4
Various	1.6	(0.8)			1
Braintree			50		4
Nashville			106	160	29
Babylon			35.8	78	31
Babylon			20.9	64.6	28
Newport News			39	151	30
NW Brooklyn			61.3	156	30
[illegible]			104		30
[illegible]				159	15
Various			6-177		6
Chicago NW			179		12
E Hamilton			112		12
Harrisburg	2.66	(1.33)			17
Harrisburg			123		3
Saugus	2.25	(1.12)			17
Average	2.38	(1.19)	88.7	129.4	
Std. Dev.	.52	(0.26)	57.1	41.6	

The nitrogen oxide emissions reported are quite variable. We feel that the Rinaldi [1] value of 1.6 lb/ton (0.8 kg/Mg) of refuse burned, which is equivalent to about 75 ppm in the flue gas, is a reasonable and conservative value for a modern waterwall incinerator.

CONTROLS

Since the NO_x levels are naturally comparatively low, the control of NO_x is not practiced on mass-burning municipal incinerators. Combustion modification techniques applicable to fossil fuel-fired-boilers either are generally not applicable to the mass-burning situation or tend to cause higher CO emissions and unacceptable boiler corrosion. One of the add-on control systems available for fossil fuel-fired-boilers has been tested in Japan [32]. The results of the test showed that the NO_x could be reduced by 60 percent by injecting NH_3 under precise control into the incinerator firebox. About 20 ppm of unreacted NH_3 remaining in the gas caused precipitates of ammonium salts to form in the economizer.

This test does not appear to establish that these reductions have been "achieved in practice" by a municipal incinerator as required in the regulations to establish LAER or BACT and thereafore should not be used to establish BACT or LAER.

CARBON MONOXIDE

EMISSIONS

Carbon monoxide is a product of incomplete combustion and for municipal incineration depends largely on the overfire air ratio, the design of the overfire air jets, and the combustion temperature. Values of CO reported in the literature are shown in Table 7. Considering these data, we have chosen a somewhat conservative 150 ppm as a reasonable estimate for a modern incinerator design using the combustion control measures now commonly used to control boiler tube wastage. This is equivalent to an emission rate of 1.9 lb/ton (0.95 kg/Mg) of refuse burned.

TABLE 7 CARBON MONOXIDE EMISSIONS

Incinerator	lb/Ton	kg/Mg	actual ppm	ppm corr. to 12% CO2	Ref.
Various	35	(18)			8
Braintree			873*	1390	4
Nashville			153	176	29
Newport News			5.2-105		30
Various			6.1-179		6
Saugus	0.17	(0.08)			17
Average			103.3	750	
Std. Dev.			67.9	-	

* Incineration problems reported

CONTROLS

The CO emissions from modern incinerators are usually limited to a few hundred ppm by combustion control measures designed to achieve good combustion and minimize boiler tube wastage. The maintenance of a minimum temperature and adequate turbulence (usually by means of overfire air jets) in the firebox – as required to control flame length, insure complete combustion, and reduce the corrosion of the boiler tubes – normally provides adequate control of CO and no additional controls are required.

HYDROCARBONS

EMISSIONS

Hydrocarbons appearing in the flue gas of an incinerator are products of incomplete combustion. They are mostly low-molecular-weight hydrocarbons, aldehydes, and organic acids with traces of high molecular-weight compounds also present. Values reported for hydrocarbon emissions from municipal incinerators are shown in Table 8. Older refractory wall incinerators frequently have higher HC and CO emissions than modern waterwall incinerators. Considering these data, we have chosen an emission rate of 0.12 lb/ton (0.06 kg/Mg) which

is equivalent to approximately 16 ppm as a reasonable value for total hydrocarbon emissions for this type of incinerator.

TABLE 8 HYDROCARBON EMISSIONS

Incinerator	THC* Kg/Mg	THC* lb/ton	THC* ppm	Aldehydes ppm	Organic Acids ppm	Ref.
Various	(0.75)	1.5				6
Various	(0.06)	0.12				1
Braintree			11.3	1.3		8
Newport News			10	0.1	1	30
Oceanside			1.5	0.26	1	30
Babylon				2.6	44	31
Various			25.5-42.5	0.15-1.06		6
[illegible]	(0.116)	0.23*				33
[illegible]	(0.002)	0.003				17
Babylon				2.3	50.5	28
Average	(0.232)	.464	18.2	1.11	29.1	
Std. Dev.	(0.35)	.70	14.4	.95	23.2	

* Total hydrocarbons

CONTROLS

To the authors' knowledge, no municipal incinerator uses any type of add-on control to reduce hydrocarbon emissions and there are no published correlations between design or operating parameters and hydrocarbon emissions; however, it is reasonable to expect that measures used to control CO will control hydrocarbons even more effectively.

HYDROCHLORIC ACID

EMISSIONS

Flue gases from municipal incinerators normally contain hydrochloric acid as a by-product of the combustion of PVC, other chlorinated plastics, and sodium chloride found in the waste. Hydrochloric acid emissions are not regulated by the U.S. EPA, but most states require the emissions to be reported and control regulations are under consideration in several states. It has been reported that only about half of the chloride in the waste is converted to hydrochloric acid [28] and some of the evolved HC1 may be removed on the ash particles [34] as the flue gases pass through the boiler and electrostatic precipitator. Emissions of hydrochloric acid reported in the literature are found in Table 9. Considering these data, we feel that 200 ppm or 3.4 lb/ton (1.7 kg/Mg) is a reasonable estimate of the hydrochloric acid emissions.

TABLE 9 HYDROCHLORIC ACID EMISSIONS

Incinerator	lb/Ton	Kg/Mg	ppm	Ref.
Various	1.8	(0.9)		6
Oberhausen*			980**	15
Oceanside			113	30
Babylon			237	31
Nashville			110	29
[illegible]	4.2	(2.1)	213	35
[illegible]	4.2	(2.1)	230	35
[illegible]	4.0	(2.0)	261	35
[illegible]	4.0	(2.0)	254	35
Various			63-1260**	6
Harrisburg			273	3
Braintree			79	8
Babylon			226	28
Average	3.55	(1.78)	200	
Std. Dev.	1.01	(0.50)	67	

*Corrected to 12% CO_2 **Data point eliminated as nonrepresentative

CONTROLS

Wet scrubbers were commonly used on municipal incinerators in the past for particulate control, and more recently for gas cooling ahead of ESPs, and the acid control they gave was incidental. These scrubbers were incapable of meeting current particulate emission standards and heat recovery boilers have largely replaced water quenching so scrubbers became uncommon on municipal incinerators. Acid gas control has been required in West Germany and Japan for several years and is now being required by several local and state agencies, most notably in California.

Wet scrubbers are being used for acid gas control on municipal incinerators in West Germany in conjunction with electrostatic precipitators, and are common on hazardous waste incinerators; however, corrosion and waste water disposal problems have restricted their use on municipal incinerators. Where acid gas control is required, dry scrubbers are now commonly used. Of the seventeen scrubbing systems we are aware of that were installed in Germany and Japan in 1980 and 1981, eleven were dry scrubbers.

FLUORIDES

EMISSIONS

Traces of hydrogen fluoride from the combustion of fluorinated plastics or similar materials appear in the flue gas from municipal incinerators. There are no federal regulations limiting the emissions of fluorides from municipal incinerators, however the PSD regulations require that the fluoride emissions be estimated and reported. The emissions of fluorides from municipal incinerators reported in the literature are shown in Table 10.

EXHIBIT 4-3.3

TABLE 11. EMISSION FACTORS FOR OTHER CRITERIA POLLUTANTS FROM COAL COMBUSTION[a]

Pollutant	Emission factor			
	Average		Range	
	g/kg	lb/ton	g/kg	lb/ton
Sulfur oxides (as SO_2)	32	64	18 - 52	35 - 104
Nitrogen oxides (as NO_2)	2.1	4.2	1.7 - 2.9	3.4 - 5.9
Hydrocarbons (as CH_4)	0.003	0.005	0.002 - 0.005	0.003 - 0.01

[a] Data are for coal combustion in a unit suited to cofiring of refuse-derived and fossil fuels.

4.1.5 NITROGEN OXIDES (NOX)

FROM REFERENCE "A", TABLE 15, (EXHIBIT 4-5) UNDER THE RDF-FIRED SPREADER STOKER TYPE,

UNCONTROLLED NOX EMISSION IN LB/1.0E6 BTU

= 0.02 TO 0.63

CONVERT LB/1.0E6 TO LB/TON,

.02 LB/1.0E6 BTU X 6164 BTU/LB X 2000 LB/TON = 0.25 LB/TON

0.63 LB/1.0E6 BTU X 6164 BTU/LB X 2,000 LB/TON = 7.76 LB/TON

THEREFORE,

UNCONTROLLED TOTAL NOX EMISSION IN LB/TON

= 0.25 TO 7.76

4.0 LB/TON IS SELECTED FOR NOX EMISSION FACTOR AND IS REPRESENTATIVE OF THE MEDIAN VALUES OF THE DATA BASES USED.

EXHIBIT 4-5

Table 15

Uncontrolled NOx Emissions at Refuse-Burning Facilities*

Type of Facility	NOx Emissions			
	Concentrations (ppmv, dry)+		Emission Rates grams/GJ (lb/10^6 Btu)++	
	Low	High	Low	High
Mass Burning Refractory Wall	53	165	4.3 (.01)	30 (.07)
Mass Burning Waterwall	74	262	30 (.07)	180 (.42)
RDF Fired Spreader Stoker	79	427	8.6 (.02)	270 (.63)
Rotary Kiln	111	196	56 (.13)	99 (.23)

* Data obtained from Appendix B

\+ Concentrations corrected to 12% CO_2

++ Rates based on HHV of refuse "as-fired"

4.1.6 LEAD (PB)

FROM REFERENCE "A", TABLE 42, (EXHIBIT 4-6.1)
ESP CONTROLLED PB EMISSION IN LB/1.0E6 BTU
= 1.91E-5 TO 1.8E-3

CONVERT LB/1.0E6 TO LB/TON,
1.91E-5 LB/1.0E6 BTU X 6164 BTU/LB X 2000 LB/TON
= 0.000235 LB/TON

1.8E-3 LB/1.0E6 BTU X 6164 BTU/LB X 2000 LB/TON
= 0.0222 LB/TON

THEREFORE,
ESP CONTROLLED PB EMISSION IN LB/TON
= 0.000235 TO 0.0222

FROM REFERENCE "E",
TABLES 82-09-05.2.5, 8-09-05.2.6, 82-09-05.2.7, AND 82-09-05.2.8 (EXHIBITS 4-62, 4-6.3, 4-6.4 AND 4-6.5 RESPECTIVELY) SHOW THE DEVELOPMENT OF PB EMISSION FACTOR. FROM TABLE 82-09-05.2.8,
CONTROLLED PB EMISSION = 2.995 TO 12.328 LB/1000 TON
= 0.003 TO 0.0123 LB/TON

ALTHOUGH THE REFERENCE "A" DATA INDICATES THE 0.0014 LB/TON CONTROLLED EMISSION FACTOR (GIVEN IN THE AUTHORITY'S INITIAL SUBMITTAL) HAS BEEN ACHIEVED, IN VIEW OF THE REFERENCE "E" DATA, IT IS PRUDENT TO INCREASE THE 0.0014 LB/TON PREDICTION BY AN ORDER OF MAGNITUDE TO 0.014 LB/TON. REFERENCE TO MAXIMUM AMBIENT AIR QUALITY IMPACTS, DISPLAYED IN TABLE 5-11, PAGE 69 OF REFERENCE F, INDICATES THAT THE 10-FOLD INCREASE IN PB EMISSIONS WILL NOT JEOPARDIZE MAINTENANCE OF AMBIENT AIR QUALITY STANDARDS AS REGARDS PB.

TM

EXHIBIT 4-6.1

Table 42

Estimated Total Heavy Metal Emission Rates (#/10^6 Btu) For Refuse-Fired Units

Element	Baghouse	ESP
Antimony (Sb)	$5.32 \times 10^{-8} - 7.78 \times 10^{-6}$	$1.48 \times 10^{-6} - 3.5 \times 10^{-1}$
Arsenic (As)	$2.75 \times 10^{-9} - 1.13 \times 10^{-7}$	$1.10 \times 10^{-7} - 9.11 \times 10^{-6}$
Beryllium (Be)	$7.13 \times 10^{-11} - 1.43 \times 10^{-9}$	$4.81 \times 10^{-9} - 6.42 \times 10^{-8}$
Cadmium (Cd)	$4.5 \times 10^{-8} - 3.73 \times 10^{-6}$	$1.8 \times 10^{-6} - 1.67 \times 10^{-4}$
Chromium (Cr)	$9.49 \times 10^{-9} - 1.21 \times 10^{-7}$	$3.8 \times 10^{-7} - 2.17 \times 10^{-5}$
Copper (Cu)	$7.32 \times 10^{-8} - 1.10 \times 10^{-6}$	$2.54 \times 10^{-6} - 1.16 \times 10^{-4}$
Lead (Pb)	$8.74 \times 10^{-7} - 1.75 \times 10^{-5}$	$1.91 \times 10^{-5} - 1.8 \times 10^{-3}$
Manganese (Mn)	$4.26 \times 10^{-9} - 1.01 \times 10^{-6}$	$4.69 \times 10^{-7} - 7.4 \times 10^{-5}$
Mercury (Hg)	$3.4 \times 10^{-5} - 2.16 \times 10^{-4}$	$3.4 \times 10^{-5} - 2.16 \times 10^{-4}$
Molybdenum (Mo)	$6.52 \times 10^{-9} - 2.3 \times 10^{-5}$	$3.46 \times 10^{-8} - 1.39 \times 10^{-4}$
Nickel (Ni)	$9.39 \times 10^{-11} - 1.67 \times 10^{-7}$	$1.88 \times 10^{-8} - 1.33 \times 10^{-5}$
Selenium (Se)	$7.44 \times 10^{-11} - 1.49 \times 10^{-4}$	$6.45 \times 10^{-8} - 4.19 \times 10^{-4}$
Tin (Sn)	$8.68 \times 10^{-8} - 1.43 \times 10^{-5}$	$1.61 \times 10^{-6} - 6.48 \times 10^{-4}$
Vanadium (V)	$7.18 \times 10^{-10} - 1.55 \times 10^{-7}$	$1.08 \times 10^{-7} - 6.97 \times 10^{-6}$
Zinc (Zn)	$8.14 \times 10^{-6} - 1.63 \times 10^{-5}$	$6.98 \times 10^{-5} - 4.40 \times 10^{-3}$

Source: Appendix C

EXHIBIT 4-6.2

October 25, 1983

RESOURCE RECOVERY FACILITY DESIGN
NORTH SANTA CLARA COUNTY SOLID WASTE MANAGEMENT AUTHORITY

TABLE 82-09-05.2.5
Emission Factors for TSP & HCl Based on Total Feed Material

	UNCONTROLLED*				CONTROLLED**			
Category	I	II	III	Coal	I	II	III	Coal
T S P lb/ton	25	20	134	128	0.125	0.100	0.670	0.640
HCl lb/ton	1.4	NA	3.2	0.4	0.140	NA	0.320	0.040

Category Definitions

I - Mass-fired MSW Combustion w/o Heat Recovery
II - Mass-fired MSW Combustion with Heat Recovery
III - RDF Combustion with Heat Recovery

T S P	Total Suspended Particulates
HCl	Hydrochloric Acid

Emissions given in lb of emission per ton of total feed:
MSW for Categories I & II
RDF for Catogory III

* Reference: An Evaluation of Emission Factors For
Waste-to-Energy Systems - Executive Summary
by G.M. Rinaldi, T.R. Blackwood,
D.L. Harris & K.M. Tackett
Monsanto Research Corp. Dayton, Ohio
Table 6 for TSP Uncontrolled Emissions)
Table 13 for HCl Uncontrolled Emissions)
29 May 1979
USEPA Contract No. 68-03-2550, Task II

** Assume Controlled Emissions as follows:
99.5% Efficiency for TSP
90.0% " " HCl

NA - No data available

EXHIBIT 4-6.3

HAYDEN-WEGMAN/CAROLLO
engineers

October 25, 1983

RESOURCE RECOVERY FACILITY DESIGN
NORTH SANTA CLARA COUNTY SOLID WASTE MANAGEMENT AUTHORITY

TABLE 82-09-05.2.6
Concentractions of Trace Elements in Uncontrolled Particulate Emissions

UNCONTROLLED CONCENTRATIONS ppm				
Element	Category I	Category II	Category III	Coal
Antimony	–[a]	260 – 620	0.4 – 10	7 – 20
Arsenic	–[a]	50 – 70	20 – 80	20 – 120
Barium	–[a]	270 – 540	–[a]	–[a]
Bromine	–[a]	420 – 2,400	–[a]	–[a]
Cadmium	–[a]	380 – 820	0.3 – 1.4	0.6 – 1.0
Chlorine	–[a]	>10,000	–[a]	–[a]
Chromium	–[a]	50 – 560	5 – 20	6 – 8
Cobolt	–[a]	10 – 100	0.6 – 2.0	0.4 – 1.5
Copper	–[a]	420 – 590	10 – 50	6 – 7
Iron	–[a]	970 – 1,090	700 – 2,410	2,350 – 2,800
Lead	–[a]	11,600 – 17,500	1,220 – 2,930	340 – 380
Manganese	–[a]	420 – 1,400	10 – 20	20 – 40
Nickel	–[a]	–[a]	3 – 20	6 – 20
Selenium	–[a]	<90	10 – 40	10 – 50
Silver	–[a]	110 – 200	–[a]	–[a]
Tin	–[a]	2,600 – 5,000	50 – 150	20 – 30
Zinc	–[a]	>10,000	860 – 3,770	180 – 560

[a] Data Not Available

Reference: An Evaluation of Emission Factors For
Waste-to-Energy Systems - Executive Summary
by G.M. Rinaldi, T.R. Blackwood,
D.L. Harris & K.M. Tackett
Monsanto Research Corp., Dayton, Ohio
(Tables 14, 15, 16 & 17)
29 May 1979
USEPA Contract No. 68-03-2550, Task II

Category Definitions: See Table 82-09-05.2.5

ppm = parts per million

EXHIBIT 4-6.4

HAYDEN-WEGMAN/CAROLLO
engineers

October 25, 1983

RESOURCE RECOVERY FACILITY DESIGN
NORTH SANTA CLARA COUNTY SOLID WASTE MANAGEMENT AUTHORITY

TABLE 82-09-05.2.7
Concentrations of Trace Elements in Controlled Particulate Emissions

CONTROLLED CONCENTRATIONS ppm				
Element	Category I	Category II	Category III	Coal
Antimony	610 - 12,600	460 - 1,000	2 - 180	10 - 150
Arsenic	80 - 510	50 - 100	140 - 740	20 - 680
Barium	40 - 1,700	270 - 540	-[a]	-[a]
Bromine	320 - 6,700	350 - 1,200	-[a]	-[a]
Cadmium	520 - 2,300	670 - 1,150	0.2 - 10	2 - 8
Chlorine	99,000 - 330,000	>10,000	-[a]	-[a]
Chromium	70 - 1,800	130 - 260	60 - 100	30 - 40
Cobolt	2 - 30	5 - 50	4 - 40	3 - 30
Copper	970 - 6,800	620 - 800	50 - 280	30 - 40
Iron	1,700 - 18,000	2,000 - 2,130	6,940 - 17,300	13,200 - 18,200
Lead	50,000 - 155,000	18,100 - 34,200	4,470 - 18,400	1,050 - 1,790
Manganese	170 - 5.700	140 - 490	110 - 240	100 - 140
Nickel	40 - 440	-[a]	20 - 190	30 - 40
Selenium	10 - 120	<30	20 - 430	30 - 40
Silver	40 - 2,000	50 - 110	-[a]	-[a]
Tin	8,500 - 15,100	1400 - 5000	260 - 870	30 - 270
Zinc	47,000 - 240,000	>10,000	4,360 - 17,200	910 - 3340

[a] Data Not Available

Reference: See Table 82-09-05.2.6

Category Definitions: See Table 82-09-05.2.5

EXHIBIT 4-6.5

HAYDEN-WEGMAN/CAROLLO
engineers

October 25, 1983

RESOURCE RECOVERY FACILITY DESIGN
NORTH SANTA CLARA COUNTY SOLID WASTE MANAGEMENT AUTHORITY

TABLE 82-09-05.2.8

Controlled Emissions of Trace Elements

CONTROLLED EMISSIONS		lb/1000 ton
Element	Category II	Category III
Antimony	0.046-0.10	0.0013-0.121
Arsenic	0.005-0.01	0.094-0.496
Barium	0.027-0.054	-[a]
Bromine	0.035-0.120	-[a]
Cadmium	0.067-0.115	0.0001-0.0067
Chlorine	>1	-[a]
Chromium	0.013-0.026	0.040-0.067
Cobolt	0.0005-0.005	0.0027-0.027
Copper	0.062-0.080	0.034-0.188
Iron	0.200-0.213	4.650-11.591
Lead	1.810-3.420	2.995-12.328
Manganese	0.014-0.049	0.074-0.161
Nickel	-[a]	0.013-0.127
Selenium	<0.003	0.013-0.288
Silver	0.005-0.011	-[a]
Tin	0.140-0.500	0.174-0.583
Zinc	>1	2.921-11.524

Controlled Emissions in lb/1000 tons is product of data shown in Tables 82-09-05.2.5 and 82-09-05.2.7

EXHIBIT 4-6.5

October 25, 1983

RESOURCE RECOVERY FACILITY DESIGN
NORTH SANTA CLARA COUNTY SOLID WASTE MANAGEMENT AUTHORITY

TABLE 82-09-05.2.8

Controlled Emissions of Trace Elements

CONTROLLED EMISSIONS lb/1000 ton		
Element	Category II	Category III
Antimony	0.046-0.10	0.0013-0.121
Arsenic	0.005-0.01	0.094-0.496
Barium	0.027-0.054	-[a]
Bromine	0.035-0.120	-[a]
Cadmium	0.067-0.115	0.0001-0.0067
Chlorine	>1	-[a]
Chromium	0.013-0.026	0.040-0.067
Cobolt	0.0005-0.005	0.0027-0.027
Copper	0.062-0.080	0.034-0.188
Iron	0.200-0.213	4.650-11.591
Lead	1.810-3.420	2.995-12.328
Manganese	0.014-0.049	0.074-0.161
Nickel	-[a]	0.013-0.127
Selenium	<0.003	0.013-0.288
Silver	0.005-0.011	-[a]
Tin	0.140-0.500	0.174-0.583
Zinc	>1	2.921-11.524

Controlled Emissions in lb/1000 tons is product of data shown in Tables 82-09-05.2.5 and 82-09-05.2.7

4.1.7 BERYLLIUM (BE)

FROM REFERENCE "A", TABLE 42, PAGE 206, (EXHIBIT 4-7.1)

ESP CONTROLLED BE EMISSION IN LB/1.0E6 BTU

= 4.81E-9 TO 6.42E-8

CONVERT LB/1.0E6 BTU TO LB/TON,

4.81E-9 LB/1.0E6 BTU X 6164 BTU/LB X 2000 LB/TON

= 0.593E-6 LB/TON

6.42E-8 LB/1.0E6 BTU X 6164 BTU/LB X 2000 LB/TON

= 0.792E-6 LB/TON

THEREFORE,

ESP CONTROLLED BE EMISSION IN LB/TON

= 0.0593E-6 TO 0.792E-6 LB/TON

FROM REFERENCE "A", TABLE 40, PAGE 200, (EXHIBIT 4-7.2)

UNCONTROLLED BE EMISSION = 1.08 MICROGRAM/MJ (AVERAGE)

3.00 MICROGRAM/MJ (PEAK)

= 2.51E-6 LB/1.0E6 BTU (AVERAGE)

= 7.00E-6 LB/1.0E6 BTU (PEAK)

CONVERT LB/1.0E6 BTU TO LB/TON.

2.51E-6 LB/1/0E6 BTU X 6164 BTU/LB X 2000 LB/TON

= 31.0E-6 LB/TON

7.00E-6 LB/1.0E6 BTU X 6164 BTU/LB X 2000 LB/TON

= 86.5E-6 LB/TON

FROM REFERENCE "E", TABLE 82-09-05.2.4,

(EXHIBIT 4-7.3)

ESP CONTROLLED BE EMISSION = 4E-4 LB/1000 TON

= 0.4E-6 LB/TON

9.0E-6 LB/TON IS SELECTED FOR BE EMISSION FACTOR BASED ON CONSIDERATION OF THE DATA BASES USED.

TM

EXHIBIT 4-7.1

Table 42

Estimated Total Heavy Metal Emission Rates (#/10^6 Btu) For Refuse-Fired Units

Element	Baghouse	ESP
Antimony (Sb)	5.32×10^{-8} - 7.78×10^{-6}	1.48×10^{-6} - 3.5×10^{-1}
Arsenic (As)	2.75×10^{-9} - 1.13×10^{-7}	1.10×10^{-7} - 9.11×10^{-6}
Beryllium (Be)	7.13×10^{-11} - 1.43×10^{-9}	4.81×10^{-9} - 6.42×10^{-8}
Cadmium (Cd)	4.5×10^{-8} - 3.73×10^{-6}	1.8×10^{-6} - 1.67×10^{-4}
Chromium (Cr)	9.49×10^{-9} - 1.21×10^{-7}	3.8×10^{-7} - 2.17×10^{-5}
Copper (Cu)	7.32×10^{-8} - 1.10×10^{-6}	2.54×10^{-6} - 1.16×10^{-4}
Lead (Pb)	8.74×10^{-7} - 1.75×10^{-5}	1.91×10^{-5} - 1.8×10^{-3}
Manganese (Mn)	4.26×10^{-9} - 1.01×10^{-6}	4.69×10^{-7} - 7.4×10^{-5}
Mercury (Hg)	3.4×10^{-5} - 2.16×10^{-4}	3.4×10^{-5} - 2.16×10^{-4}
Molybdenum (Mo)	6.52×10^{-9} - 2.3×10^{-5}	3.46×10^{-8} - 1.39×10^{-4}
Nickel (Ni)	9.39×10^{-11} - 1.67×10^{-7}	1.88×10^{-8} - 1.33×10^{-5}
Selenium (Se)	7.44×10^{-11} - 1.49×10^{-4}	6.45×10^{-8} - 4.19×10^{-4}
Tin (Sn)	8.68×10^{-8} - 1.43×10^{-5}	1.61×10^{-6} - 6.48×10^{-4}
Vanadium (V)	7.18×10^{-10} - 1.55×10^{-7}	1.08×10^{-7} - 6.97×10^{-6}
Zinc (Zn)	8.14×10^{-6} - 1.63×10^{-5}	6.98×10^{-5} - 4.40×10^{-3}

Source: Appendix C

EXHIBIT 4-7.2

TM

Table 40

Observed Metal Emission Factors for Facilities Burning Coal, Oil, Refuse and Coal/Refuse Mixtures

(μg/MJ) as Fired

	Oil-Fired			Coal-Fired (Tang)+			Coal-Fired (SS)*			Coal/Refuse-Fired			Refuse-Fired		
Metal	Low	High	Avg.	Low	High	Avg.	Low	High	Avg.	Low	High	Avg.	Low	High	Avg.
As	< 0.2	49	25	20	3400	680	100	540	260	20	1300	200	16	1763	469
Be	< 0.2	< 0.3	< 0.3	7.9	40	19	7.3	15	11	< 0.85	26	9.0	<.08	3	1.08
Cd	---	---	91	8.5	1900	430	2.5	22	12	3.5	110	27	150	<1900	865
Cr	2	55	29	210	1100	540	29	2200	930	18	4100	1200	1.5	1200	499
Cu	2	180	91	250	4100	1400	28	220	130	41	< 1600	370	85	1866	870
Hg	0.6	2	1.3	0.09	35	22	---	---	< 3.2	< 5.5	< 28	16	17	390	157
Mn	< 1	10	5.5	150	740	400	17	770	330	32	< 490	240	11	3350	1909
Mo	2	72	36	360	4300	2300	---	---	---	---	---	---	27	8987	3043
Ni	200	360	230	120	730	450	28	230	110	18	58	32	2.7	764	286
Pb	20	65	43	140	17,000	5100	21	7600	1900	380	20,000	4900	5600	16,000	9531
Sb	---	---	20	7.2	1600	320	---	---	< 37	< 4.5	< 77	25	18	2060	936
Se	0.3	16	8.2	15	1400	330	14	37	26	30	89	50	8	250	95
Sn	---	---	---	---	---	120	---	- -	< 0.82	1.4	< 140	81	3.4	8017	2218
V	20	880	450	240	1300	610	< 37	790	400	< 25	670	270	3.1	151	63
Zn	3	200	100	490	39,000	8400	38	13,000	3300	440	18,000	4900	4500	91,160	33,916

Source: Appendix C, Tables C1b-C6b

\+ Tangential

* Spreader Stoker

EXHIBIT 4-7.3

HAYDEN-WEGMAN/CAROLLO
engineers

October 25, 1983

RESOURCE RECOVERY FACILITY DESIGN
NORTH SANTA CLARA COUNTY SOLID WASTE MANAGEMENT AUTHORITY

TABLE 82-09-05.2.4
Comparison of Average Non-Criteria Pollutant Metal Emissions* from MSW Combustion

Group	Element	Symbol	"C" Washington D.C. SWRC #1 Cycl. Col./ESP 0.9 lb/ton		"D" Nicosia Tray Scrub'r	"E" Braintree ESP 2.7 lb/ton		"C" Alexandria Wet Baffle 5.6 lb/ton	
			**Fly Ash	Suspended	8 lb/ton	Inlet	Outlet	**Flyash	Suspended
I	Arsenic	As	59	310 (0.28)	200	120	57 (0.15)	40	210
I	Barium	Ba	3,200	990 (0.89)	220	400	340 (0.92)	2,800	890
I	Cadmium	Cd	185	1,900 (1.71)	1,500	1,100	480 (1.29)	42	1,100
I	Chromium	Cr	780	870 (0.78)	105	270	200 (0.54)	1,330	490
I	Lead	Pb	NR	78,000 (70.20)	69,000	NR	NR	40,000	97,000
I	Mercury	Hg	NR	NR	NR	NR	0.31 (8x10^{-4})	NR	NR
I	Selenium	Se	12	39 (0.03)	49	< 25	38 (1x10^{-4})	3.4	23
I	Silver	Ag	220	1,000 (0.90)	110	165	79 (0.21)	85	390
II	Antimony	Sb	580	2,400 (2.16)	1,600	2,200	1,600 (4.32)	270	2,400
II	Beryllium	Be	NR	NR	NR	< 0.15	≤ 0.16 (4x10^{-4})		
II	Cobalt	Co	27	5 (0.0045)	2	38	17 (0.05)	12	
II	Copper	Cu	950	1,500 (1.35)	1,700	1,800	1,600 (4.32)	980	2,000
II	Manganese	Mn	2,100	410 0.37)	270	770	330 (0.89)	4,300	1,500
II	Molybdenum	Mo	NR	NR	NR	43	37 (0.10)	NR	NR
II	Nickel	Ni	NR	170 (0.15)	79	NR	NR	740	200
II	Thallium	Tl	NR	NR	NR	1.8	1.6 (0.004)	NR	NR
II	Vanadium	V	NR	NR	NR	39	24 (0.06)	135	22
II	Zinc	Zn	240,000	140,000 (126)	110,000	> 10,000	> 10,000 (> 27)	10,800	120,000

Group I metals are classified Non-Criteria Pollutants by USEPA & CDOHS
Group II metals are classified Non-Criteria Pollutants by CDOHS only
USEPA = United States Environmental Protection Agency
CDOHS = California Department of Health Services
NR = Not Reported
* Metal emissions are given in ppm concentration of metal in total particulate emissions
ppm = parts per million unless noted
( ) = lb of metal emitted/1000 ton MSW
** Collected Fly Ash
"C", "D" & "E" denote references to literature. (See page v).

4.1.8 MERCURY (HG)

FROM REFERENCE "A", TABLE 42, PAGE 206, (EXHIBIT 4-8.1)

ESP CONTROLLED HG EMISSION IN LB/1.0E6 BTU

= 3.4E-5 TO 2.16E-4

CONVERT LB/1.0E6 BTU TO LB/TON,

3.4E-5 LB/1.0E6 BTU X 6164 BTU/LB X 2000 LB/TON

= 0.000419 LB/TON

2.16E-4 LB/1.0E6 BTU X 6164 BTU/LB X 20000 LB/TON

= 0.00266 LB/TON

THEREFORE,

ESP CONTROLLED HG EMISSION IN LB/TON

= 0.000419 TO 0.00266 LB/TON

FROM REFERENCE "B", PAGE 292, (EXHIBIT 4-8.2)

CONTROLLED HG EMISSION IN LB/TON = 0.0064

0.003 LB/TON IS SELECTED FOR HG EMISSION FACTOR AND IS REPRESENTATIVE OF THE MEDIAN VALUES OF THE DATA BASES USED.

TM

EXHIBIT 4-8.1

Table 42

Estimated Total Heavy Metal Emission Rates (#/10^6 Btu) For Refuse-Fired Units

Element	Baghouse	ESP
Antimony (Sb)	$5.32\text{x}10^{-8}$ - $7.78\text{x}10^{-6}$	$1.48\text{x}10^{-6}$ - $3.5\text{x}10^{-1}$
Arsenic (As)	$2.75\text{x}10^{-9}$ - $1.13\text{x}10^{-7}$	$1.10\text{x}10^{-7}$ - $9.11\text{x}10^{-6}$
Beryllium (Be)	$7.13\text{x}10^{-11}$ - $1.43\text{x}10^{-9}$	$4.81\text{x}10^{-9}$ - $6.42\text{x}10^{-8}$
Cadmium (Cd)	$4.5\text{x}10^{-8}$ - $3.73\text{x}10^{-6}$	$1.8\text{x}10^{-6}$ - $1.67\text{x}10^{-4}$
Chromium (Cr)	$9.49\text{x}10^{-9}$ - $1.21\text{x}10^{-7}$	$3.8\text{x}10^{-7}$ - $2.17\text{x}10^{-5}$
Copper (Cu)	$7.32\text{x}10^{-8}$ - $1.10\text{x}10^{-6}$	$2.54\text{x}10^{-6}$ - $1.16\text{x}10^{-4}$
Lead (Pb)	$8.74\text{x}10^{-7}$ - $1.75\text{x}10^{-5}$	$1.91\text{x}10^{-5}$ - $1.8 \text{ x } 10^{-3}$
Manganese (Mn)	$4.26\text{x}10^{-9}$ - $1.01\text{x}10^{-6}$	$4.69\text{x}10^{-7}$ - $7.4\text{x}10^{-5}$
Mercury (Hg)	$3.4\text{x}10^{-5}$ - $2.16\text{x}10^{-4}$	$3.4\text{x}10^{-5}$ - $2.16\text{x}10^{-4}$
Molybdenum (Mo)	$6.52\text{x}10^{-9}$ - $2.3\text{x}10^{-5}$	$3.46\text{x}10^{-8}$ - $1.39\text{x}10^{-4}$
Nickel (Ni)	$9.39\text{x}10^{-11}$ - $1.67\text{x}10^{-7}$	$1.88\text{x}10^{-8}$ - $1.33\text{x}10^{-5}$
Selenium (Se)	$7.44\text{x}10^{-11}$ - $1.49\text{x}10^{-4}$	$6.45\text{x}10^{-8}$ - $4.19\text{x}10^{-4}$
Tin (Sn)	$8.68\text{x}10^{-8}$ - $1.43\text{x}10^{-5}$	$1.61\text{x}10^{-6}$ - $6.48\text{x}10^{-4}$
Vanadium (V)	$7.18\text{x}10^{-10}$ - $1.55\text{x}10^{-7}$	$1.08\text{x}10^{-7}$ - $6.97\text{x}10^{-6}$
Zinc (Zn)	$8.14\text{x}10^{-6}$ - $1.63\text{x}10^{-5}$	$6.98\text{x}10^{-5}$ - $4.40\text{x}10^{-3}$

Source: Appendix C

EXHIBIT 4.8.2

TABLE 10 FLUORIDE EMISSIONS

Incinerator	ppm	Ref.
[illegible]	20*	15
Babylon	4.8	31
Braintree	2.8	4
Babylon	5	12
Zurich	12	7
Dusseldorf	10	7
Average	6.4	
Std. Dev.	3.91	

*Corrected to 12% CO_2

Based on these data 6.5 ppm or 0.06 lb/ton (0.03 kg/Mg) has been chosen as a conservative estimate of fluoride emissions.

CONTROLS

Fluoride emission control is normally not required on municipal incinerators except in conjunction with acid gas control. Some of the fluoride appears to be associated with the particulate matter and therefore will be removed by the particulate control device while some is apparently present as a gas and would be removed in the acid gas scrubber. Very little fluoride removal data are available but it appears that the fluoride may be removed a little more efficently than the hydrochloric acid.

TRACE METALS, LEAD, MERCURY, BERYLLIUM

EMISSIONS

Some of the lead in the municipal waste is emitted with the fly ash from a municipal incinerator. The amount of lead emitted will depend upon the efficiency of the particulate control system. Some reported values of lead emissions for incinerators using electrostatic precipitators for particulate control are shown in Table 11. We have chosen 34,200 μg/g (0.034 lb/lb) of particulates or 0.012 lb/ton (0.006 kg/Mg) of refuse burned as a reasonable estimate of the lead emissions.

TABLE 11 LEAD EMISSIONS

Incinerator	μg Pb / g of Particulates	gr/dscf	mg / dscm	Ref.
Braintree		0.0024	(5.4)	4
Washington, D.C.	78,000			36
Various	18,100-34,200			3
Hamilton	5,700			6
Germany	20,100			6
Average	33,700			
Std. Dev.	25,100			

Trace amounts of mercury have been found in the emissions for municipal incinerators. Values reported in the literature are shown in Table 12. Based on the listed data, an emission of 2.4×10^{-4} gr/dscf (0.55 mg/dscm) or 0.0064 lb/ton (0.0032 kg/Mg) of refuse burned was chosen as a conservative estimate of total mercury emissions.

TABLE 12 MERCURY EMISSIONS

Incinerator	μg Hg / g of Particulates	gr/dscf	mg / dscm	Ref.
Braintree		6.1×10^{-6} particulate	(.014)	4
		2.4×10^{-4} vapor	(.55)	
Hamilton	300			6
Germany	133			6
Gent, Belgium		6.4×10^{-5} vapor	(.146)	37
Average	216	1.6×10^{-4}	(.371)	

Few data giving emissions of beryllium from municipal incinerators were found. The only reference to beryllium emissions was for the Braintree incinerator [4] where less than 0.15 μg/g of emitted particulates was reported. Using this data, based on the particulate emissions previously cited, the emissions of beryllium are estimated to be less than 5.6×10^{-8} lb/ton (2.8×10^{-8} kg/Mg) of refuse burned.

Trace quantities of a large number of other metals have been found in the fly ash from municipal incinerators. Most of them are present in very small quantities and are of little environmental concern. Concentrations of the more toxic metals are presented in Table 13.

CONTROLS

The trace metals are minor and variable constituents of the waste. Most of the metals except for mercury appear to concentrate in the bottom ash or fly ash. Data presented by Law [38], factored for the difference in efficiency between a baffle chamber and and ESP (95 percent), indicate that most of the mercury is emitted, less than 3 percent of the volatile metals (such as lead, cadmium and zinc) are emitted and less than 1 percent of the nonvolatile metals (such as barium, chromium, and copper) are emitted.

The data indicate that an effective particulate control system is about equally effective in controlling the trace metals. It is sometimes stated that a fabric filter's high efficiency for fine particulates makes it more efficient than other devices in collecting trace metals, but there is inadequate data to substantiate such superiority.

4.1.9 CHLORIDES (AS HCL)

FROM REFERENCE "B", PAGE 291, (EXHIBIT 4-9.1)

UNCONTROLLED HCL EMISSION IN LB/TON = 3.4 (200 PPM)

FROM REFERENCE "D, TABLE 82-09-05.2.5

(EXHIBIT 4-9.2) UNCONTROLLED HCL = 3.2

USE 3.5 LB/TON RDF.

EXHIBIT 4-9.1

is equivalent to approximately 16 ppm as a reasonable value for total hydrocarbon emissions for this type of incinerator.

TABLE 8 HYDROCARBON EMISSIONS

Incinerator	THC* kg/Mg	THC* lb/ton	THC* ppm	Aldehydes ppm	Organic Acids ppm	Ref.
Various	(0.75)	1.5				8
Various	(0.06)	0.12				7
Braintree			11.3	1.3		6
[illegible]			40	0.1	1	10
Oceanside			4.5	0.26	1	30
[illegible]				2.6	44	31
Various			27.5-42.5	0.15-1.06		6
Unknown	(0.116)	0.231				33
Unknown	(0.002)	0.003				7
Babylon				2.3	90.5	28
Average	(0.232)	.464	18.2	1.11	29.1	
Std. Dev.	(0.35)	.70	14.4	.95	23.2	

* Total Hydrocarbons

CONTROLS

To the authors' knowledge, no municipal incinerator uses any type of add-on control to reduce hydrocarbon emissions and there are no published correlations between design or operating parameters and hydrocarbon emissions; however, it is reasonable to expect that measures used to control CO will control hydrocarbons even more effectively.

HYDROCHLORIC ACID

EMISSIONS

Flue gases from municipal incinerators normally contain hydrochloric acid as a by-product of the combustion of PVC, other chlorinated plastics, and sodium chloride found in the waste. Hydrochloric acid emissions are not regulated by the U.S. EPA, but most states require the emissions to be reported and control regulations are under consideration in several states. It has been reported that only about half of the chloride in the waste is converted to hydrochloric acid [28] and some of the evolved HC1 may be removed on the ash particles [34] as the flue gases pass through the boiler and electrostatic precipitator. Emissions of hydrochloric acid reported in the literature are found in Table 9. Considering these data, we feel that 200 ppm or 3.4 lb/ton (1.7 kg/Mg) is a reasonable estimate of the hydrochloric acid emissions.

TABLE 9 HYDROCHLORIC ACID EMISSIONS

Incinerator	lb/Ton	kg/Mg	ppm	Ref.
Various	1.8	(0.9)		8
Oberhausen*			900**	15
Oceanside			113	30
Babylon			237	31
[illegible]			140	29
Unknown	4.2	(2.1)	213	35
Unknown	4.2	(2.1)	230	35
Unknown	4.8	(2.4)	261	35
Unknown	4.8	(2.4)	254	35
Various			63- 260**	6
Harrisburg			273	3
Braintree			79	6
Babylon			226	28
Average	3.55	(1.78)	200	
Std. Dev.	1.01	(0.50)	67	

*Corrected to 12% CO2 **Data point eliminated as nonrepresentative

CONTROLS

Wet scrubbers were commonly used on municipal incinerators in the past for particulate control, and more recently for gas cooling ahead of ESPs, and the acid control they gave was incidental. These scrubbers were incapable of meeting current particulate emission standards and heat recovery boilers have largely replaced water quenching so scrubbers became uncommon on municipal incinerators. Acid gas control has been required in West Germany and Japan for several years and is now being required by several local and state agencies, most notably in California.

Wet scrubbers are being used for acid gas control on municipal incinerators in West Germany in conjunction with electrostatic precipitators, and are common on hazardous waste incinerators; however, corrosion and waste water disposal problems have restricted their use on municipal incinerators. Where acid gas control is required, dry scrubbers are now commonly used. Of the seventeen scrubbing systems we are aware of that were installed in Germany and Japan in 1980 and 1981, eleven were dry scrubbers.

FLUORIDES

EMISSIONS

Traces of hydrogen fluoride from the combustion of fluorinated plastics or similar materials appear in the flue gas from municipal incinerators. There are no federal regulations limiting the emissions of fluorides from municipal incinerators, however the PSD regulations require that the fluoride emissions be estimated and reported. The emissions of fluorides from municipal incinerators reported in the literature are shown in Table 10.

EXHIBIT 4-9.2

October 25, 1983

RESOURCE RECOVERY FACILITY DESIGN
NORTH SANTA CLARA COUNTY SOLID WASTE MANAGEMENT AUTHORITY

TABLE 82-09-05.2.5
Emission Factors for TSP & HCl Based on Total Feed Material

	UNCONTROLLED*				CONTROLLED**			
Category	I	II	III	Coal	I	II	III	Coal
T S P lb/ton	25	20	134	128	0.125	0.100	0.670	0.640
HCl lb/ton	1.4	NA	3.2	0.4	0.140	NA	0.320	0.040

Category Definitions

I -	Mass-fired MSW Combustion w/o Heat Recovery
II -	Mass-fired MSW Combustion with Heat Recovery
III -	RDF Combustion with Heat Recovery

T S P	Total Suspended Particulates
HCl	Hydrochloric Acid

Emissions given in lb of emission per ton of total feed:
MSW for Categories I & II
RDF for Catogory III

* Reference: An Evaluation of Emission Factors For
Waste-to-Energy Systems - Executive Summary
by G.M. Rinaldi, T.R. Blackwood,
D.L. Harris & K.M. Tackett
Monsanto Research Corp. Dayton, Ohio
Table 6 for TSP Uncontrolled Emissions)
Table 13 for HCl Uncontrolled Emissions)
29 May 1979
USEPA Contract No. 68-03-2550, Task II

** Assume Controlled Emissions as follows:
99.5% Efficiency for TSP
90.0% " " HCl

NA - No data available

4.1.10 FLOURIDES (AS HF)

FROM REFERENCE "A", TABLE 20, (EXHIBIT 4-10)

UNCONTROLLED HF EMISSION IN LB/1.0E6 BTU

= 0.003 TO 0.004

CONVERT LB/1.0E6 BTU TO LB/TON,

0.003 LB/1.0E6 BTU X 6164 BTU/LB X 2000 LB/TON

= 0.037 LB/TON

0.004 LB/1.0E6 BTU X 6164 BTU/LB X 2000 LB/TON

= 0.0493 LB/TON

THEREFORE,

UNCONTROLLED HF EMISSION IN LB/TON

0.04 LB/TON IS SELECTED FOR HF EMISSION FACTOR AND IS REPRESENTATIVE OF THE MEDIAN VALUES OF THE DATA BASES USED.

Table 20

Uncontrolled Emissions of SO_2, HCl and HF at Refuse-Burning Facilities

Type of Facility	Concentrations (ppmv, dry)+						Emission Rates grams/GJ++ ($lbs/10^6$ Btu)					
	SO_2		HCl		HF		SO_2		HCl		HF	
	Low	High	Low	High	Low	High	Low	High	Low	High	Low	High
Mass-Burning Refractory Wall	47	131	76	665	3.0	13	32 (.074)	360 (.84)	8.6 (.02)	430 (1.0)	0.9 (.002)	4.3 (.01)
Mass-Burning Waterwall	12	442			NA	NA	17 (.040)	310 (.720)			NA	NA
Rotary Kiln	48	118			NA	NA	26 (.06)	69 (.16)			NA	NA
RDF-Fired Spreader Stoker	162	472	610	654	11	15	130 (.300)	770 (1.790)	160 (.37)	190 (.44)	1.3 (.003)	1.7 (.004)

NA = Not Available

\+ Corrected to 12% CO_2
++ Rates based on HHV of fuel "as-fired"

Source: Appendix B

EXHIBIT 4-10

4.1.11 SULFURIC ACID MIST (H_2SO_4)

IN THE DEVELOPMENT OF SO2 EMISSION FACTOR, WE HAVE ASSUMED THAT ALL SULFUR CONTENT IN RDF IS COMPLETELY CONVERTED TO SO2.

THEREFORE, THERE SHALL BE NO SULFUR LEFT TO FORM SULFURIC ACID MIST.

HOWEVER REFERENCE "B", PAGE 293 (EXHIBIT 4-11) STATES

UNCONTROLLED H2SO4 EMISSION = 0.04 LB/TON

CONTROLLED H2SO4 EMISSION = 0.04 X (1 - .99) = 0.0004 LB/TON

THE BOILING POINT OF SULFURIC ACID IS 626°F. AT THE STACK EXIT GAS TEMPERATURE OF 450 °F, THE SULFURIC ACID THAT IS FORMED FROM SO2, H20 AND 02 IS PRESUMED TO BE A LIQUID AEROSOL WHICH WOULD BE ADSORBED ON FLY ASH PARTICULATE AND COLLECTED AT AN EFFICIENCY OF 99%.

EXHIBIT 4-11

TABLE [illegible] CONCENTRATIONS OF SELECTED TRACE METALS IN MUNICIPAL INCINERATOR FLY ASH

Metal	μg/g Ref. [illegible]	 Ref. 36	 Ref. [illegible]	 Average	lb/Ton*	Kg/Mg
Arsenic	57	310	50-100	130	4.4 x 10^{-5}	(2.2x10^{-5})
Barium	240	990	270-540	540	1.8 x 10^{-4}	(0.9x10^{-4})
Cadmium	480	1900	670-1150	1100	3.8 x 10^{-4}	(1.9x10^{-4})
Chromium	200	870	130-260	360	1.2 x 10^{-4}	(0.6x10^{-4})
Copper	1600	1500	620-800	1100	3.8 x 10^{-4}	(1.9x10^{-4})
Nickel		170		170	5.8 x 10^{-5}	(2.9x10^{-5})
Zinc	1%	14%	1%	5.3%	1.8 x 10^{-2}	(0.9x10^{-2})

*Based on particulate emissions of 0.34 lb/Ton (0.17 Kg/Mg)

SULFURIC ACID MIST

EMISSIONS

Very little data is available on emissions of sulfuric acid mist from municipal incinerators. Data from Harrisburg [3] give 0.0014 or gr/scf (3.2 mg/scm) which is 1.6 percent of the SO_2 emission rate. On the basis of the 2.4 lb/ton (1.2 kg/Mg) rate previously established for SO_2 emissions, a sulfuric acid mist emissions rate of 0.04 lb/ton (0.02 kg/Mg) of refuse burned can be calculated.

CONTROLS

Sulfric acid mist will be a vapor at high temperatures but, especially in the presence of moisture, will condense as an aerosol at lower temperatures. Most common pollution control systems will have low capture efficiencies but dry acid gas scrubbers (especially those utilizing fabric filters) should provide good control.

DIOXINS AND FURANS

EMISSIONS

Traces of polychlorinated dibenzo-*p*-dioxins and dibenzofurans have been identified in the emissions from a number of municipal incinerators abroad and in the U.S. The source or mechanism of formation of these compounds has not yet been discovered. Several theories have been proposed to account for their presence: they may be present in the feed and pass through the incinerator undestroyed; they may be formed from precursors such as chlorinated phenols, chlorinated benzenes, or PCBs, present in the feed; or they may be formed by the reaction of traces of chlorine present in the feed with complex organics formed in the combustion process. Much of the published data on dioxin emissions are not quantitative and the quantitative data available, as shown in Table 14, are very scattered. Several reports reviewing the literature on dioxins have been published [45, 46], but most of the data cited in this paper were derived from original literature sources where available.

In general, the variability of the data makes averages derived from it statistically meaningless except possibly for tetrachlorodibenzo-*p*-dioxin (TCDD) which has received the most attention from the investigators. It can be observed that the emissions reported for the Dutch incinerators are considerably higher than the other reported emissions (TCDD = 54 vs. 5.8 ng/g for ESP fly ash and 100 versus 2 ng/g for stack particulates); that the more highly chlorinated isomers, particularly the hexa and hepta chloro isomers, are more plentiful than the tetrachloro isomers; that there is several times as much dioxin in the emitted particulate as in that collected in the ESP; and that there can be appreciable dioxins in the vapor phase. There is no indication of why the reported emissions from the Dutch and the U.S. incinerator are so high compared to the rest, however the preponderance of evidence seems to favor the lower numbers.

Considering the available data, we conclude that the best estimate of TCDD emissions possible is 1 X 10^{-9} to 5 X 10^{-7} lb/ton (0.5 X 10^{-9} to 2.5 X 10^{-7} kg/Mg) of refuse burned and that total dioxin emissions are possibly a factor of 10 higher. Data presented by Cavallaro [42] and others indicate that the concentration of the toxic isomer 2,3,7,8-TCDD will be about 5 percent of the total TCDD

4.1.12 HYDROGEN SULFIDE, TOTAL REDUCED SULFUR, REDUCED SULFUR COMPOUNDS, VINYL CHLORIDE AND ASBESTOS

BASED ON REFERENCE "B", PAGE 295, (EXHIBIT 4-12) NO EMISSIONS OF HYDROGEN SULFIDE, TOTAL REDUCED SULFUR, REDUCED SULFUR COMPOUNDS, VINYL CHLORIDE AND ASBESTOS ARE EXPECTED.

EXHIBIT 4-12

TABLE 16 POLYNUCLEAR AROMATIC HYDROCARBON EMISSIONS

Incinerator	µg/g	(µg/m³)	lb/Ton*	g/Mg	Ref.
Braintree		(20)	4×10^{-6}	(2×10^{-6})	4
Various	0.6		0.3×10^{-6}	(0.2×10^{-6})	43
Unknown	0.2		2×10^{-6}	(1×10^{-6})	47
[illegible], England		(0.20)	0.8×10^{-6}	(0.4×10^{-6})	44
Various			40.3×10^{-6}	(20×10^{-6})	1
Average			10×10^{-6}	(5×10^{-6})	

*Calculated

shown in Table 16. Considering the wide variation of the available data, we have selected an average value of 1×10^{-5} lb per ton (0.5×10^{-5} kg/Mg) of refuse burned or 30 µg/g of emitted particulates.

POLYCHLORINATED BIPHENYLS (PCBs)

PCBs have been found in trace amounts in several municipal incinerator emissions. These materials probably result from incomplete destruction of traces of PCBs found in the waste feed. Since the manufacture and distribution of PCBs is now prohibited, the amounts found in the refuse, and therefore the amount in the emissions, can be expected to decline in the future. The reported PCB emissions are shown in Table 17.

Considering these data, 5×10^{-6} gr/dscf (0.011 mg/dscm) or 1.3×10^{-4} lb/ton (0.65×10^{-4} kg/Mg) is a reasonably conservative value for PCB emissions from municipal incinerators.

TABLE 17 PCB EMISSIONS

Incinerator	lb/Ton	(kg/Mg)	gr/dscf	(mg/dscm)	Ref.
Chicago NW	1.2×10^{-4}	(0.6×10^{-4})	5.5×10^{-6}	(0.013)	49
Dade Co			4.8×10^{-6}*	(0.011)	50
Braintree			1.6×10^{-6}**	(0.0037)	4

* As Aroclor ① 1254 ** As decachlorobiphenyl

ASBESTOS

No data were found on the emissions of asbestos from municipal incinerators. Some asbestos may occur in municipal waste and small quantities may be suspended in the flue gas, but the particulate control equipment is expected to remove most of it and the emissions are expected to be insignificant.

VINYL CHLORIDE, H_2S, TRS*

No reports of the detection of these materials in the emissions from a municipal incinerator were found. Since these materials would be readily oxidized under the conditions prevailing in the incinerator, we conclude that there will be essentially zero emissions of these materials and that BACT is the standard combustion controls normally used on these units.

CONCLUSIONS

Published data on the emissions from municipal incinerators have been used to derive emission factors for a modern mass burning, waterwall municipal waste incinerator equipped with an electrostatic precipitator. These emission factors are summarized in Table 18.

TABLE 18 SUMMARY OF EMISSION FACTORS

Pollutant	Concentrations ppm or (gr/dscf)	lb/Ton
Particulates	(0.02)*	0.30
Sulfur Dioxide	60	2.4
Nitrogen Oxides	75	1.4
Carbon Monoxide	150	1.9
Hydrocarbons	16	0.12
Hydrochloric Acid	200	3.0
Fluorides	6.5	0.06
Lead	(6.8×10^{-5})*	0.012
Mercury	(2.9×10^{-5})	0.0064
Beryllium	(3.0×10^{-9})*	5.1×10^{-8}
Sulfuric Acid Mist	(0.0023)*	0.04
Tetrachlorodibenzo-p-dioxins		4×10^{-8}
Polynuclear Aromatics		1.0×10^{-5}
Polychlorinated Biphenyls		1.3×10^{-4}

*Corrected to 12% CO_2

These factors have been used in several instances to provide the emissions estimates for proposed incinerators for use in permit applications and environmental impact reports.

State-of-the-art control systems have been identified for each emitted pollutant as an aid in identifying BACT and LAER. A summary of these systems is presented in Table 19. In general, we have concluded that while thermal nitrogen oxide reduction systems and fabric filters show promise as improved pollution control systems, there is yet insufficient data in the literature to prove that they will maintain the claimed efficiencies under normal incinerator operating conditions.

---

*Total reduced sulfur.

4.1.13 DIOXIN

THE EMISSION FACTOR WAS CALCULATED FOR THE TETRA HOMOLOGUE (CONTAINING FOUR CHLORINE ATOMS) TCDD WHICH CONTAINS THE ISOMER 2,3,7,8 - TCDD OF GREATEST TOXICITY AND CONCERN.

FROM REFERENCE "G", TABLE 3-2 (EXHIBIT 4-13), MASS EMISSION RATE FOR TCDD BASED ON THE ANALYSIS MADE FOR THE PROPOSED NEW YORK CITY BROOKLYN NAVY YARD 3000 TPD MASS BURN WATERWALL PLANT, ASSUMING THE WORST CASE CONDITION WHERE ALL DIOXIN ARE EMITTED IN GASEOUS FORM (EQUALLY UNCONTROLLED WHETHER AN ELECTROSTATIC PRECIPITATOR OR BAG HOUSE IS USED), IS GIVEN AT 1.07 ug/sec. THIS IS CALCULATED TO BE EQUIVALENT TO THE EMISSION FACTOR 8.5 E-08 LB/TON GIVEN IN TABLE 4-1 OF REFERENCE "F" AS FOLLOWS:

$$\frac{1.07\ \frac{ug}{sec} \times \frac{E\text{-}6\ g}{1\ ug} \times \frac{lb}{453.6g}}{\frac{3000\ \text{ton MSW}}{24\ X\ 60\ X\ 60\ sec}} = 0.07\ E\text{-}6\ \text{lb/ton MSW}$$

MSW @ 82% combustible.

$$\frac{0.07\ E\text{-}6\ lb}{0.82 \times \text{ton MSW}} = \frac{8.5\ E\text{-}8\ lb}{\text{ton Combustible}}$$

= 8.5 E-8 lb/ton RDF

THE ISOMER 2,3,7,8 TCDD IS SHOWN IN EXHIBIT 4-13 TO BE 0.07 ug/sec, OR APPROXIMATELY 7% OF THE TOTAL TCDD MASS EMISSION RATE OF 1.07 ug/sec. THEREFORE, USING 8.5 E-8 LB/TON RDF (DERIVED FROM THE 1.07 ug/sec MASS EMISSION RATE FOR TCDD) IS A CONSERVATIVE OVERSTATEMENT OF THE EMISSION FACTOR FOR THE ISOMER 2, 3, 7, 8 TCDD.

EXHIBIT 4-13

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.

Question No. 2

Provide documentation that an electrostatic precipitator (ESP) will remove 99% of sulfuric acid mist at an exit gas temperature of 450 °F.

Response:

See paragraph 4.1.11 above.

Question No. 3

The emission factor for dioxins appears to be based on the emission factor for the Brooklyn Navy Yard project which will use a dry scrubber and baghouse for control. What is the emission factor when an ESP is used as the only control device.

Response:

See paragraph 4.1.13 above.

SECTION II

BEST AVAILABLE CONTROL TECHNOLOGY

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SECTION II

BEST AVAILABLE CONTROL TECHNOLOGY

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PALM BEACH COUNTY SOLID WASTE AUTHORITY
SOLID WASTE-TO-ENERGY FACILITY
REPORT ON AIR QUALITY IMPACTS ANALYSIS
RESPONSE TO FLORIDA DER SUFFICIENCY REVIEW

1. BEST AVAILABLE CONTROL TECHNOLOGY ISSUES

This Section II of the Supplemental Report addresses the issues of Best Available Control Technology (BACT) as raised by FDER in Questions 4, 5 and 6 of their August 23, 1985 Interoffice Memorandum and also by National Park Service's Southeast Regional Service, as presented in their four-page Technical Review, transmitted by National Park Service August 16, 1985 letter to FDER and submitted by FDER to the Authority along with FDER's questions.

2. FDER QUESTIONS ON BACT

FDER questions 4, 5 and 6 addressing the BACT issues, are replicated herewith for reference as follows:

Question No. 4:

Wet scrubbers were not evaluated in the BACT because they produced an "aesthetically undesirable water vapor plume." Provide all the appropriate evaluations of wet scrubbers for the proposed BACT.

Question No. 5:

The proposed BACT compares an ESP to a dryscrubber and baghouse. This is not a valid comparison. Submit the necessary data comparing a baghouse to an ESP and a dryscrubber with a baghouse to scrubber with an ESP.

Question No. 6:

A BACT economic analysis which evaluates unit cost per ton of pollutant removed should include all the pollutants; for example, dry scrubbers should address acid, SO_2 etc. Resubmit the economic data for all of the control systems which are to be evaluated.

3. EXPANDED BACT ANALYSIS

By way of responding to the FDER questions, the BACT analysis has been expanded to encompass six air pollution control alternatives as follows:

3.1 Alternative 3-3
Electrostatic Precipitator

A four-field ESP is being specified capable of controlling effluent particulate matter (PM) emissions to 0.025 grains/DSCF @ 12% CO_2. Because of anticipated deterioration of performance as the facility ages, the BACT analysis conservatively assumes in-service PM emissions at 0.03 grains/DSCF @ 12% CO_2.

Cost development for this alternative is given in Table 3-3 (Sheet 1 and 2).

A partial listing of refuse - burning facilities equipped with ESPs is shown on Exhibit II-1, Table 30) taken from the May 24, 1984 issue of the CARB report.

PALM BEACH COUNTY SOLID WASTE AUTHORITY
SOLID WASTE-TO-ENERGY FACILITY
"REPORT ON AIR QUALITY IMPACTS ANALYSIS"
OCTOBER 5, 1985

<u>TABLE 3 - 3</u> (Sheet 1 of 2)

ELECTROSTATIC PRECIPITATOR SYSTEM COSTS
700 TPD UNIT

1.	EMISSION LIMIT, GRAINS/DSCF @ 12% CO2	0.03
2.	REMOVAL EFFICIENCY, PERCENT	99.00
3.	PARTICULATE REMOVED, TPY (NOTE 1)	5861
4.	CONSTRUCTION COST	$2,300,000
5.	BONDING FACTOR (NOTE 2)	1.6
6.	CAPITAL COST (5 X 4)	$3,680,000
7.	CAPITAL RECOVERY FACTOR (20 YEARS TERM AT 11%)	0.12558
8.	ANNUAL CAPITAL COST (7 X 6)	$462,000
9.	OPERATING AND MAINTENANCE COST	
	A. ELECTRICITY (2.9 MILLION KWH @ 5 CENTS)	$145,000
	B. WATER	$0
	C. LABOR (2 MEN: 1/2 MEN PER SHIFT @ $30,000)	$60,000
	D. MAINTENANCE @ 2% OF CONSTRUCTION COST	$46,000
	E. LIME, 0 TPY @ $150/TON	$0
	F. WASTE HANDLING & DISPOSAL (5861 TPY TSP @ $10/TON)	$59,000
	G. REHEAT STEAM (0 MMBTUH @ $6/MMBTU)	$0
	TOTAL OPERATING & MAINTENANCE COST	$310,000
10.	TOTAL ANNUAL COST	$772,000

TABLE 3 - 3 (Sheet 2 of 2)

ELECTROSTATIC PRECIPITATOR SYSTEM COSTS (SHEET 2 OF 2)
700 TPD UNIT

11. UNIT COST:

PER TON MSW (260,000 TPY)	$2.97
PER TON RDF (182,000 TPY)	$4.24
PER TON PARTICULATE (5861 TPY)	$131.72

NOTE:

1. PARTICULATE REMOVED ANNUALLY BY ELECTROSTATIC PRECIPITATOR SYSTEM

   = 21400 TPY UNCONTROLLED TSP X 0.83 AVAILABILITY X 1 UNIT/3 UNITS

   X .99 EFFICIENCY = 5861 TPY

2. INCLUDES BUSINESS RISK & EFFICACY INSURANCE; DEBT SERVICE OPERATING & RENEWAL & REPLACEMENT FUNDS, INTEREST DURING CONSTRUCTION AND FINANCING COSTS.

EXHIBIT II-1

Table 30

Partial Listing of Refuse-Burning Facilities Equipped with Electrostatic Precipitators

Facility	Capacity (T/D)	Furnace Type	Gas Flow m^3/min (ACFM)	Gas Temp. °C (°F)	SCA	Input KVA	Gas Velocity M/S (ft/sec)	Design Efficiency g/Nm^3, (gr/scf)	Tested Efficiency g/Nm^3, dry* (gr/scf)	
									Performance	Later
Montreal, Canada	4 x 300	WW	3,170 (112,000)	280 (536)	161	35	1.68 (5.5)	0.23 (0.0875)	[1970]** .03 (0.0133)	[1971]** .18 (0.0799)
Southwest Brooklyn, New York	1 x 250	R	3,707 (131,000)	288 (550)	149	47	1.34 (4.4)	0.24 (0.093)	[1970] .26 (0.114)	[1971] .33 (0.146)
South Shore, New York	1 x 250	R	3,849 (136,000)	316 (600)	147	33	1.68 (5.5)	0.24 (0.093)	[1970] .13 (0.056)	NR
Dade County, Florida (early facility)	1 x 300	R	8,094 (286,000)	299 (570)	175	48	1.19 (3.9)	0.25 (0.094)	[1970] .06 (0.027)	
Chicago Northwest, Illinois	4 x 4	WW	3,113 (110,000)	232 (450)	182	40	.88 (2.9)	0.13 (0.05)	[1971] .05-.07 (0.02-0.03)	[1975] .07 (0.03)
Braintree, Massachusetts	2 x 120	WW	906 (32,000)	316 (600)	182	19	.95 (3.1)	0.22 (0.086)	[1970] .25 (0.108)	[1978] .19 (0.083)
Washington, D.C.	6 x 250	R	3,702 (130,800)	288 (550)	204	77	1.25 (4.1)	0.53 (0.2)	[1972] .13 (0.0548)	NR
Harrisburg, Pennsylvania	2 x 360	WW	2,830 (100,000)	210 (410)	200	40	1.07 (3.5)	0.24 (0.093)	[1973] .13-.15 (0.055-0.065)	[1974] .09-.20 (0.039-0.083)
Quebec, Canada	4 x 250	WW	2,830 (100,000)	260 (500)	NR	NR	NR	0.26 (0.106)	[1974] .22 (0.095)	NR
Saugus, Massachusetts	2 x 600	WW	3,195 (112,913)	198 (389)	NR	NR	NR	NR	[1980] .025	NR
Kure, Japan	2 x 165	Rotary WW	943 (33,333)	222 (432)	NR	NR	NR	NR	[1981] .030	
Albany, New York	2 x 300	SS WW	1,799 (63,579)	184 (364)	NR	NR	NR	NR	[1982] 0.027	
Hamilton, Ontario, Canada	2 x 300	SS WW	1,695 (59,900)	255 (492)	NR	NR	NR	NR		[1979] .16
Pinellas, Florida	2 x 1000	WW	5,207 (184,000)	238 (462)	NR	NR	NR	NR	[1983] .025	
Resource Recovery Dade County, Florida	4 x 750	SS WW	13,756 (486,000)	237 (459)	NR	NR	NR	NR	[1983] 0.05	

WW = Waterwall
R = Refractory lined
NR = Not reported
SS = Spreader stoker

* Concentrations corrected to 12% CO_2)
** [Year of test]

3.2 Alternative 3-4

Bag Filter with Cyclone Collector

The specific response to FDER Question 5, the Bag Filter (BF) with Cyclone Collector (CC) system is now shown as Alternative 3-4. This system is capable of controlling effluent PM emissions to 0.01 grains/DSCF @ 12% CO_2. The Cyclone Collector is installed upstream of the bag Filter in order to arrest incandescent particles from passing into the Bag Filters and burning holes in the bags.

Although the Bag Filter system is theoretically more efficient, it has limited experience in municipal waste-to-energy combustion systems, much of which has been bad. Bag blinding and bag failures (e.g. pin holes and tears) have been experienced at these installations.

Cost development for the Bag Filter with Cyclone Collector Alternative is given in Table 3-4 (Sheets 1 and 2).

A partial listing of bag filter facilities on refuse-burning plants is shown on Exhibit II-2 (Table 31) taken from the May 24, 1984 issue of the CARB report.

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TABLE 3 - 4 (Sheet 1 of 2)

BAG FILTER WITH CYCLONE COLLECTOR SYSTEM COSTS
700 TPD UNIT

1.	EMISSION LIMIT, GRAINS/DSCF @ 12% CO2	0.01
2.	REMOVAL EFFICIENCY, PERCENT	99.90
3.	PARTICULATE REMOVED, TPY (NOTE 1)	5915
4.	CONSTRUCTION COST	$2,070,000
5.	BONDING FACTOR (NOTE 2)	1.6
6.	CAPITAL COST (5 X 4)	$3,312,000
7.	CAPITAL RECOVERY FACTOR (20 YEARS TERM AT 12%)	0.13388
8.	ANNUAL CAPITAL COST (7 X 6)	$443,000
9.	OPERATING AND MAINTENANCE COST	
	A. ELECTRICITY (3.08 MILLION KWH @ 5 CENTS)	$155,000
	B. WATER	$0
	C. LABOR (4 MEN: 1 MAN PER SHIFT @ $30,000)	$120,000
	D. MAINTENANCE @ 3% OF CONSTRUCTION COST	$62,000
	E. LIME, 0 TPY @ $150/TON	$0
	F. WASTE HANDLING $ DISPOSAL (5915 TPY TSP @ $10/TON)	$59,000
	G. REHEAT STEAM (0 MMBTUH @ $6/MMBTU)	$0
	TOTAL OPERATING & MAINTENANCE COST	$396,000
10.	TOTAL ANNUAL COST	$839,000

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TABLE 3 - 4 (Sheet 2 of 2)

BAG FILTER WITH CYCLONE COLLECTOR SYSTEM COSTS
700 TPD UNIT

11. UNIT COST:

PER TON MSW (260,000 TPY)	$3.23
PER TON RDF (182,000 TPY)	$4.61
PER TON PARTICULATE (5915 TPY)	$141.8~~7~~4

NOTE:

1. PARTICULATE REMOVED ANNUALLY BY CYCLONE COLLECTOR AND BAGFILTER SYSTEM
   = 21400 TPY UNCONTROLLED TSP X 0.83 AVAILABILITY X 1 UNIT/3 UNITS
   X .999 EFFICIENCY = 5915 TPY

2. SAME AS TABLE 3-3

EXHIBIT II-2

Table 31

Partial Listing of Fabric Filter Applications to Refuse-Burning Facilities

Location of Facility (Ref)	Capacity (MT/D)+	Gas Flowrate (m^3/min)	Gas Temp. (°C)	Air-to-Cloth Ratio (m^3/min-m^3)	TSP Outlet Concentration grams/Nm^3 (grains/dscf)	△ P (cm, w.g.)	Application
Pasadena, California (429)	NA	8.5	230	1.4	0.002 (0.008)	10 - 15	MSW Slip-stream
Sas Fe, Switzerland (430)	36	422	260	0.76		6 - 12	MSW Full-scale
E. Bridgewater,* Massachusetts (431)	330	2500	260	0.6	0.04 (0.02)	5 - 8	(closed) Full-scale
Nashville, Tennessee (432)	NA			1.2	0.002 (0.008)	NR	Slip-stream
Saugus, Massachusetts (433)	1360	1132	209	NR	0.020 (0.008)	10 - 15	Slip-stream on one unit
Gallatin,** Tennessee (434)	76	676	171	(Apitron) 10.0	0.071 (0.029)	13 - 40	Full-scale
Framingham, Massachusetts (435)	453	4500	176		0.049 (0.02)	13	Full-scale
Tsushima, Japan (436)	136	1091	93 - 160	NR	(0.01)	NR	Full-scale
Malmo, Sweden (437)	456	3100	392	NR	guaranteed 0.059 (0.02)	Reported higher than anticipated	Full-scale
Susanville, California (438)	87	715	215	1.61	design 0.02 (0.01)	design 10 - 15	Full-scale
City of Hamm, West Germany (439)	961	4x1383.9	171	NR	under construction (1984)	NR	MSW Full-scale

NR -- Not reported

* East Bridgewater facility is currently not in operation.

** Apitron unit was removed due to operation problems.

3.3 Alternative 3-5
Dry Scrubber & Electrostatic Precipitator

In specific response to FDER Question 5, the Dry Scrubber and ESP alternative was developed and costs thereof are displayed in Table 3-5 (Sheet 1 and 2).

In addition to removal of particulates, this system is intended to effect acid gas control. A 70% collection efficiency is anticipated for SO_2 emissions and a 90% collection efficiency for both HCl and HF.

TABLE 3 - 5 (Sheet 1 of 2)

DRY SCRUBBER AND ELECTROSTATIC PRECIPITATOR SYSTEM COSTS
700 TPD UNIT

1.	EMISSION LIMIT, GRAINS/DSCF @ 12% CO2	0.03
2.	REMOVAL EFFICIENCY, PERCENT	99.00
3.	PARTICULATE REMOVED, TPY (NOTE 1)	5861
4.	CONSTRUCTION COST	$5,300,000
5.	BONDING FACTOR (NOTE 4)	1.6
6.	CAPITAL COST (5X4)	$8,480,000
7.	CAPITAL RECOVERY FACTOR (20 YEARS TERM AT 12%)	0.13388
8.	ANNUAL CAPITAL COST (7X6)	$1,135,000
9.	OPERATING AND MAINTENANCE COST	
	A. ELECTRICITY (3.76 MILLION KWH @ 5 CENTS)	$188,000
	B. WATER (80 GPM @ $0.7/1000 GAL)	$18,000
	C. LABOR (8 MEN; TWO PER SHIFT @ $30,000)	$240,000
	D. MAINTENANCE	$106,000
	E. LIME, 2200 TPY @ $150/TON	$300,000
	F. WASTE HANDLING & DISPOSAL (5861 TPY TSP; +2200 TPY LIME; 863 TPY SO2 & HCL; AT $10/TON) (NOTE 2)	$87,000
	G. REHEAT STEAM (5 MMBTUH @ $6/MMBTU)	$262,000
	TOTAL OPERATING & MAINTENANCE COST	$1,201,000
10.	TOTAL ANNUAL COST	$2,336,000

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TABLE 3 - 5 (Sheet 2 of 2)

DRY SCRUBBER AND ELECTROSTATIC PRECIPITATOR

11. UNIT COST:

PER TON MSW (260,000 TPY)	\$8.98
PER TON RDF (182,000 TPY)	\$12.84
PER TON PARTICULATE (5861 TPY)	\$398.57
PER TON PARTICULATE & ACID GAS (6724 TPY)	\$347.41

NOTE:

1. PARTICULATE REMOVED ANNUALLY BY DRY SCRUBBER AND ELECTROSTATIC PRECIPITATOR SYSTEM

   = 21400 TPY UNCONTROLLED TSP X 0.83 AVAILABILITY X 1 UNIT/3 UNITS
   X .99 EFFICIENCY = 5861 TPY

2. DRY SCRUBBER AND ELECTROSTATIC PRECIPITATOR SYSTEM ALSO REMOVE ACID GAS, SO2 REMOVED ANNUALLY BY DRY SCRUBBER AND ELECTROSTATIC PRECIPITATOR SYSTEM = 2957 TPY UNCONTROLLED SO2 X 0.83 AVAILABILITY X 1 UNIT/3 UNITS X .7 EFFICIENCY = 573 TPY

   HCL REMOVED ANNUALLY BY DRY SCRUBBER AND ELECTROSTATIC PRECIPITATOR SYSTEM = 1150 TPY UNCONTROLLED SO2 X 0.83 AVAILABILITY X 1 UNIT/3 UNITS X .9 EFFICIENCY = 287 TPY

   HF REMOVED ANNUALLY BY DRY SCRUBBER AND ELECTROSTATIC PRECIPITATOR SYSTEM = 13.2 TPY UNCONTROLLED SO2 X 0.83 AVAILABILITY X 1 UNIT/3 UNITS X .9 EFFICIENCY = 3 TPY

   TOTAL ACID GAS REMOVED = 863 TPY

3. TOTAL PARTICULATE & ACID GAS REMOVED = 6724 TPY

4. SAME AS NOTE 2, TABLE 3-3.

Dry Scrubber installations, followed mainly by ESP's, but also by Bag Filters (referred to as Fabric Filters) have been installed in Europe and Japan, as shown in Exhibit II-3. Aside from the Framingham, MA installation of a Dry Scrubber/Fabric Filter on a non-heat recovery incinerator (see Exhibit II-2), there are presently no other such intallations in the United States, although several are being planned.

EXHIBIT II-3

DRY SCRUBBER INSTALLATIONS

Japan

Name	Type	Year
Yokamama City #1	FF	78
Yokamama City #2	ESP	80
Yokamama City #3	ESP	79
Ohnojo	ESP	80
Chiba	N/A	81
Kanto	ESP	81
Sayai City	ESP	80
Sendai City	ESP	80
Yokamama	ESP	84
Yokamama	ESP	80
Nishisonogi-gun	ESP	82
Yokamama	ESP	80
Shrouka	ESP	82
Kamakuta	ESP	81
Tshushima	FF	83

West Germany

Name	Type	Year
Pineburg	ESP	74
Hamburg	ESP	77
Vienna	N/A	78
Hamburg	ESP	79
Munich	ESP	80
Dusseldorf	ESP	80
Oberhausen	FF	78
Dusseldorf	ESP	80
Dusseldrof	ESP	N/A
Hamm	FF	84
Dusseldorf	ESP	84

Key: ESP - Electrostatic Precipitator
FF - Fabric Filter
N/A - Not Available

3.4 Alternative 3-6

Dry Scrubber & Bag Filter

The Dry Scrubber & Bag Filter alternative submitted with the Authority's original application has been revised and is included herewith. The revised costs for this alternative are displayed in Table 3-6 (Sheets 1 and 2).

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TABLE 3 - 6 (Sheet 1 of 2)

DRY SCRUBBER AND FILTER SYSTEM COSTS
700 TPD UNIT

1.	EMISSION LIMIT, GRAINS/DSCF @ 12% CO2	0.01
2.	REMOVAL EFFICIENCY, PERCENT	99.9
3.	PARTICULATE REMOVED, TPY (NOTE 1)	5915
4.	CONSTRUCTION COST	$5,000,000
5.	BONDING FACTOR (NOTE 4)	1.6
6.	CAPITAL COST (5 X 4)	$8,000,000
7.	CAPITAL RECOVERY FACTOR (20 YEARS TERM AT 13%)	0.14235
8.	ANNUAL CAPITAL COST (7 X 6)	$1,139,000
9.	OPERATING AND MAINTENANCE COST	
A.	ELECTRICITY (4.27 MILLION KWH @ 5 CENTS)	$213,000
B.	WATER (80 GPM @ $0.7/1000 GAL)	$18,000
C.	LABOR (8 MEN; TWO PER SHIFT @ $30,000)	$240,000
D.	MAINTENANCE	$120,000
E.	LIME, 2,200 TPY @ $150/TON	$300,000
F.	WASTE HANDLING & DISPOSAL (59 TPY TSP; +2000 TPY LIME; +863 TYP S02 & HCL; AT $10/TON) NOTE 2)	88,000
G.	REHEAT STEAM (5 MMBTUH @ $6/MMBTU	$262,000
	TOTAL OPERATING & MAINTENANCE COST	$1,241,000
10.	TOTAL ANNUAL COST	$2,380,000

TABLE 3 - 6 (Sheet 2 of 2)

DRY SCRUBBER AND BAG FILTER SYSTEM COSTS
700 TPD UNIT

11. UNIT COST:

PER TON MSW (260,000 TPY)	$9.15
PER TON RDF (182,000 TPY)	$13.08
PER TON PARTICULATE (5915 TPY)	$402.37
PER TON PARTICULATE & ACID GAS (6778 TPY)	$351.14

NOTE:

1. PARTICULATE REMOVED ANNUALLY BY DRY SCRUBBER AND BAGFILTER SYSTEM
= 21400 TPY UNCONTROLLED TSP X 0.83 AVAILABILITY X 1 UNIT/3 UNITS
X .999 EFFICIENCY = 5915 TPY

2. DRY SCRUBBER AND BAGFILTER SYSTEM ALSO REMOVE ACID GAS,
SO2 REMOVED ANNUALLY BY DRY SCRUBBER AND BAGFILTER SYSTEM
= 2957 TPY UNCONTROLLED SO2 X 0.83 AVAILABILITY X 1 UNIT/3 UNITS
X .7 EFFICIENCY = 573 TPY
HCL REMOVED ANNUALLY BY DRY SCRUBBER AND BAGFILTER SYSTEM
= 1150 TPY UNCONTROLLED SO2 X 0.83 AVAILABILITY X 1 UNIT/3 UNITS
X .9 EFFICIENCY = 287 TPY
HF REMOVED ANNUALLY BY DRY SCRUBBER AND BAGFILTER SYSTEM
= 13.2 TPY UNCONTROLLED SO2 X 0.83 AVAILABILITY X 1 UNIT/3 UNITS
X .9 EFFICIENCY = 3 TPY
TOTAL ACID GAS REMOVED = 863 TPY

3. TOTAL PARTICULATE & ACID GAS REMOVED = 6778 TPY

4. SAME AS NOTE 2, TABLE 3-3.

3.5 Alternative 3-7

ESP & Wet Scrubber

In response to FDER Question 4, two wet scrubber alternatives were developed. Alternative 3-7 provides a wet scrubber downstream of an ESP and Alternative 3-8 provides a wet scrubber downstream of a Bag Filter, the latter described further in paragraph 3.6 below.

Costs for the ESP/Wet Scrubber alternative are displayed in Table 3-7 (Sheets 1 and 2) Particulate matter and acid gas collection efficiencies for the ESP/Wet Scrubber system are designed to correspond to respective efficiencies for these emissions provided in the Dry Scrubber/ESP alternative.

Temperature of the stack gases for the Wet Scrubber alternatives approximate 150°F whereas for the Dry Scrubber alternatives, the temperature is about 250%. To compensate for the lower temperature gases, the Wet Scrubber alternatives provide for additional reheat of stack gases relative to the reheat used in the Dry Scrubber systems.

TABLE 3 - 7 (Sheet 1 of 2)

WET SCRUBBER AND ELECTROSTATIC PRECIPITATOR SYSTEM COSTS
700 TPD UNIT

1.	EMISSION LIMIT, GRAINS/DSCF @ 12% CO2	0.03
2.	REMOVAL EFFICIENCY, PERCENT	99.00
3.	PARTICULATE REMOVED, TPY (NOTE 1)	5861
4.	CONSTRUCTION COST	$5,220,000
5.	BONDING FACTOR (NOTE 4)	1.6
6.	CAPITAL COST (5X4)	$8,480,000
7.	CAPITAL RECOVERY FACTOR (20 YEARS TERM AT 13%)	0.14235
8.	ANNUAL CAPITAL COST (7X6)	$1,207,000
9.	OPERATING AND MAINTENANCE COST	
	A. ELECTRICITY (3.6 MILLION KWH @ 5 CENTS)	$180,000
	B. WATER (80 GPM @ $0.7/1000 GAL)	$29,000
	C. LABOR (9 MEN; 2.25 PER SHIFT @ $30,000)	$270,000
	D. MAINTENANCE	$104,000
	E. LIME, 2200 TPY @ $150/TON	$330,000
	F. WASTE HANDLING & DISPOSAL (5861 TPY TSP; +2200 TPY LIME; 863 TPY SO2 & HCL; AT $10/TON) (NOTE 2)	$89,000
	G. REHEAT STEAM (10 MMBTUH @ $6/MMBTU)	$524,000
	TOTAL OPERATING & MAINTENANCE COST	$1,526,000
10.	TOTAL ANNUAL COST	$2,733,000

TABLE 3 - 7 (Sheet 2 of 2)

DRY SCRUBBER AND ELECTROSTATIC PRECIPITATOR

11. UNIT COST:

PER TON MSW (260,000 TPY)	$10.51
PER TON RDF (182,000 TPY)	$15.02
PER TON PARTICULATE (5861 TPY)	$466.30
PER TON PARTICULATE & ACID GAS (6724 TPY)	$406.45

NOTE:

1. PARTICULATE REMOVED ANNUALLY BY DRY SCRUBBER AND ELECTROSTATIC PRECIPITATOR SYSTEM

   = 21400 TPY UNCONTROLLED TSP X 0.83 AVAILABILITY X 1 UNIT/3 UNITS
   X .989 EFFICIENCY = 5861 TPY

2. DRY SCRUBBER AND ELECTROSTATIC PRECIPITATOR SYSTEM ALSO REMOVE ACID

   GAS, SO2 REMOVED ANNUALLY BY DRY SCRUBBER AND ELECTROSTATIC PRECIPITATOR SYSTEM = 2957 TPY UNCONTROLLED SO2 X 0.83 AVAILABILITY X 1 UNIT/3 UNITS

   X .7 EFFICIENCY = 573 TPY

   HCL REMOVED ANNUALLY BY DRY SCRUBBER AND ELECTROSTATIC PRECIPITATOR

   SYSTEM = 1150 TPY UNCONTROLLED SO2 X 0.83 AVAILABILITY X 1 UNIT/3 UNITS

   X .9 EFFICIENCY = 287 TPY

   HF REMOVED ANNUALLY BY DRY SCRUBBER AND ELECTROSTATIC PRECIPITATOR SYSTEM

   = 13.2 TPY UNCONTROLLED SO2 X 0.83 AVAILABILITY X 1 UNIT/3 UNITS

   X .9 EFFICIENCY = 3 TPY

   TOTAL ACID GAS REMOVED = 863 TPY

3. TOTAL PARTICULATE & ACID GAS REMOVED = 6724 TPY

4. SAME AS NOTE 2, TABLE 3-3.

3.6 Alternative 3-8

Bag Filter & Wet Scrubber

Table 3-8 (Sheet 1 and 2) provide the cost development for the Bag Filter/Wet Scrubber alternative. Since the Wet Scrubber is installed downstream of the Bag Filter, a Cyclone Collector must be provided upstream of the Bag Filter, as was done for Alternative 3-4. Particulate matter and acid gas collection efficiencies for the Bag Filter/Wet Scrubber System are designed to correspond to respective efficiencies for these emissions provided in the Dry Scrubber/Bag Filter alternative.

TABLE 3 - 8 (Sheet 1 of 2)

WET SCRUBBER AND BAG FILTER SYSTEM COSTS
700 TPD UNIT

1.	EMISSION LIMIT, GRAINS/DSCF @ 12% CO2	0.01
2.	REMOVAL EFFICIENCY, PERCENT	99.9
3.	PARTICULATE REMOVED, TPY (NOTE 1)	5915
4.	CONSTRUCTION COST	$4,990,000
5.	BONDING FACTOR (NOTE 4)	1.6
6.	CAPITAL COST (5 X 4)	$7,984,000
7.	CAPITAL RECOVERY FACTOR (20 YEARS TERM AT 14%)	0.15099
8.	ANNUAL CAPITAL COST (7 X 6)	$1,206,000
9.	OPERATING AND MAINTENANCE COST	
	A. ELECTRICITY (4.07 MILLION KWH @ 5 CENTS)	$204,000
	B. WATER (80 GPM @ $0.7/1000 GAL)	$29,000
	C. LABOR (9 MEN; 2.25 PER SHIFT @ $30,000)	$270,000
	D. MAINTENANCE (INCL. BAG REPLACEMENT)	$122,000
	E. LIME, 2200 TPY @ $150/TON	$330,000
	F. WASTE HANDLING & DISPOSAL (5915 TPY TSP; +2200 TPY LIME; +863 TPY SO2 & HCL; AT $10/TON) (NOTE 2)	$90,000
	G. REHEAT STEAM (10 MMBTUH @ $6/MMBTU)	$524,000
	TOTAL OPERATING & MAINTENANCE COST	$1,569,000
10.	TOTAL ANNUAL COST	$2,775,000

TABLE 3 - 8 (Sheet 2 of 2)

WET SCRUBBER AND BAG FILTER SYSTEM COSTS
700 TPD UNIT

11. UNIT COST:

PER TON MSW (260,000 TPY)	$10.67
PER TON RDF (182,000 TPY)	$15.25
PER TON PARTICULATE (5915 TPY)	$469.15
PER TON PARTICULATE & ACID GAS (6778 TPY)	$409.41

NOTE:

1. PARTICULATE REMOVED ANNUALLY BY DRY SCRUBBER AND BAGFILTER SYSTEM
   = 21400 TPY UNCONTROLLED TSP X 0.83 AVAILABILITY X 1 UNIT/3 UNITS
   X .999 EFFICIENCY = 5915 TPY
2. DRY SCRUBBER AND BAGFILTER SYSTEM ALSO REMOVE ACID GAS,
   SO2 REMOVED ANNUALLY BY DRY SCRUBBER AND BAGFILTER SYSTEM
   = 2957 TPY UNCONTROLLED SO2 X 0.83 AVAILABILITY X 1 UNIT/3 UNITS
   X .7 EFFICIENCY = 573 TPY
   HCL REMOVED ANNUALLY BY DRY SCRUBBER AND BAGFILTER SYSTEM
   = 1150 TPY UNCONTROLLED SO2 X 0.83 AVAILABILITY X 1 UNIT/3 UNITS
   X .9 EFFICIENCY = 287 TPY
   HF REMOVED ANNUALLY BY DRY SCRUBBER AND BAGFILTER SYSTEM
   = 13.2 TPY UNCONTROLLED SO2 X 0.83 AVAILABILITY X 1 UNIT/3 UNITS
   X .9 EFFICIENCY = 3 TPY
   TOTAL ACID GAS REMOVED = 863 TPY
3. TOTAL PARTICULATE & ACID GAS REMOVED = 6778 TPY
4. SAME AS NOTE 2, TABLE 3-3.

4. COMPARATIVE BACT ANALYSIS

Table 3.9 summarizes salient cost and performance factors for the six alternatives evaluated for the BACT analysis.

For each of the alternatives, the following information is displayed:

1) Alternative No.
2) Capsule System Description
3) Interest Rate
4) Construction Cost
5) Annual Capital Cost
6) Annual O & M Cost
7) Total Annual Cost
8) Unit Costs
    a) Per Ton MSW
    b) Per Ton RDF
    c) Per Ton Fly Ash Including Acid Gas Products

In addition, an Incremental Analysis (9) is performed to evaluate incremental benefits of the more advanced and costlier systems relative to the baseline, taken to be Alternative 3-3, the Electrostatic Precipitator.

A unique approach was used in the analysis in order to provide a basis for factoring System Reliability in evaluating alternative technologies. This was done by assigning different interest rates to alternative systems based on a judgement as to relative riskiness of the technology, considering its track record. This is akin to a Standard & Poors or Moody rating being assigned to capital projects which, along with market forces, determines interest rates on a bond issue.

For example an interest rate of 11% was used to calculate Annual Capital Cost for the proven ESP technology, whereas 12% was used for Bag Filter technology. When the risk of Bag Filter operation was compounded by the complexity of a Dry Scrubber addition, interest rate for the alternative rose to 13%. With a Wet Scrubber addition to the Bag Filter, an appropriate interest rate was judged to be 14% and so forth.

5. UNIT COSTS

Unit cost are useful in comparing alternatives, particularly in line item 8c, where comparison are made for cost portion of pollutant removed including acid gas as well as particulate matter.

6. RANKINGS

Based on the data, ranking of alternatives are developed as follows:

Rank #	Alternative	System Description
1	3-3	ESP
2	3-4	BF
3	3-5	Dry Scr./ESP
4	3-6	Dry Scr./BF
5	3-7	ESP/Wet Scr.
6	3-8	BF/Wet Scr.

7. INCREMENTAL ANALYSIS

Incremental analysis was performed to determine incremental cost for:

(a) Improved particulate matter (PM) collection of the BF relative to the ESP and

(b) Improved PM and acid gas collection of the Dry Scr/ESP alternative relative to the PM collection of the BH alone.

(c) Improved PM and acid gas collection of the Dry Scr./ESP alternative relative to the PM collection of the ESP alone.

For case (a), the BF Alternative 3-4 is seen to have the capabilities of collecting an additional 54 TPY of PM at an incremental annual cost of $67,000 relative to Alternative 3-3. This affords a unit cost of $1240.74 for each ton of additional PM and compares unfavorably to the $131.72 per ton PM unit cost for ESP alone (Alternative 3-3).

For case (b), the Dry Scrubber/ ESP Alternative 3-5 is seen to have the capabilities of collecting an additional 809 TPY of combined PM and acid gas products at an annual cost of $1,497,000 relative to Alternative 3-4. This affords a unit cost of $1,850.43 for each ton of additional PM and acid gas collected and compares unfavorable to the $141.84 per ton PM unit cost for the BF Alternative 3-4.

For case (c), the Dry Scrubber ESP Alternative 3-5 is seen to have the capabilities of collecting an additinal 863 TPY of combined PM and acid gas products at an incremental annual cost of $1,564,000 relative to Alternative 3-3. This affords a unit cost of $1812.28 for the acid gas collected and may be difficult to justify since the Air Quality Analysis shows that acid gas concentrations in ambient air pose no danger to public health.

8. BACT, CALIFORNIA VS. FLORIDA

The BACT analysis, required by PSD review, addresses energy, economic and environmental impacts for alternative emission control strategies. BACT is defined in the 40 CFR 52.21 as "An emission limitation based on the maximum degree of reduction of each pollutant emitted which the Department, taking into account, energy environmental and economic impacts and other costs, production processes and available methods, system, and techniques, for control of each pollutant".

Although the stagnant ambient air conditions of California may give case for CARB's definition of BACT to include scrubbers and bag filters, it has not been demonstrated that they are needed in well-ventilated Florida environs. A moderate approach to defining BACT for a locality should take into account background levels, planned new facilities and meteorological conditions. This in fact has been done in the Air Quality

Analysis performed with the conclusion that emissions from the proposed facility will not adversely impact ambient air quality.

TABLE 3-9

BACT ANALYSIS OF ALTERNATIVE AIR POLLUTION CONTROL SYSTEMS FOR 700 TPD RDF-FIRED SPREADER STOKER BOILER

1. Alternative No.	3-3	3-4	3-5	3-6	3-7	3-8
2. APC System Descr.	ESP	BF	Dry Scr/ESP	Dry Scr/BF	ESP/Wet Scr.	BF/Wet Scr.
3. Interest Rate **	11%	12%	12%	13%	13%	14%
4. Construction Cost	$2,300,000	$2,070,000	$5,300,000	$5,000,000	$5,220,000	$4,990,000
5. Annual Capital Costs	462,000	443,000	1,135,000	1,139,000	1,207,000	1,206,000
6. Annual O & M	310,000	396,000	1,201,000	1,241,000	1,526,000	1,569,000
7. Total Annual Cost	772,000	839,000	2,336,000	2,380,000	2,733,000	2,775,000
8. Unit Costs:						
a) Per Ton MSW	$2.97/Ton	$3.23/Ton	$8.98/Ton	$9.15/Ton	$10.51/Ton	$10.67/Ton
b) Per Ton RDF	$4.24/Ton	$4.61/Ton	$12.84/Ton	$13.08/Ton	$15.02/Ton	$15.25/Ton
c) Per Ton Fly Ash*	$131.72/Ton	$141.84/Ton	$347.41/Ton	$351.14/Ton	$406.45/Ton	$409.41/Ton
9. Incremental Analysis	Rank #1	Rank #2	Rank #3	Rank #4	Rank #5	Rank #6
A. Total Annual Cost	$772,000	$839,000	$2,336,000	$2,380,000	$2,733,000	$2,775,000
B. Total Annual Cost of Next Lowest #Rank	-	772,000	839,000	2,336,000	2,380,000	2,733,000
C. = (A - B)	-	$67,000	$1,497,000	$44,000	$353,000	$42,000
D. Fly Ash* Collected	5,861 TPY	5,915 TPY	6,724 TPY	6,778 TPY	6,724 TPY	6,778 TPY
E. Fly Ash* Collected in Next Lowest# Cost Rank	-	5,861 TPY	5,915 TPY	6,724 TPY	6,778 TPY	6,724 TPY
F. (D - E)	-	54 TPY	809 TPY	54 TPY	-54 TPY	54 TPY
G. = (A - B)÷ (D - E)	-	$1,240.74/Ton	$1,850.43/Ton	$814.81/Ton	-$6,537.04/Ton	$777 77/Ton
H. Total Annual Cost of 2nd Next Lowest# Rank	-	-	$772,000			
I. Fly Ash* Collected in 2nd Next Lowest #Rank	-	-	5,861 TPY			
J. = (A - H)	-	-	$1,564,000			
K. = (D - I)	-	-	863 TPY			
L. = (A - H) ÷ (D - I)	-	-	$1,812.28 Ton			

* Including Acid Gas Fly Ash
** Interest Rate Proportioned to Technology Risk

BACT = Best Available Control Technology
ESP = Electrostatic Precipitator
BF = Bag Filter
Scr. = Scrubber

SECTION III

RESPONSE TO

FDER QUESTIONS 7, 8, 9, & 10

ON

(7) HOSPITAL WASTE

(8) ANNUAL EMISSIONS

(9) AIR QUALITY RECEPTORS

(10) TECHNICAL & ADMINISTRATIVE REVIEW PROTOCOL

SECTION III

RESPONSE TO

FDER QUESTIONS 7, 8, 9, & 10

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PALM BEACH COUNTY SOLID WASTE AUTHORITY
SOLID WASTE - TO - ENERGY FACILITY
REPORT ON AIR QUALITY IMPACTS ANALYSIS
RESPONSE TO FLORIDA DER SUFFICIENCY REVIEW

QUESTION NO. 7 - ON HOSPITAL WASTE:

Will any hospital waste or "red bag" waste be incinerated at this facility? If so, please quantify the amounts, composition, and the source of these materials.

Response:

As noted in *Vol. I - Application, Chapter 3 Page 3.2, Paragraph 1:

> "Pathological, biological and other hazardous wastes will not be processed at this facility."

QUESTION NO. 8 - ON ANNUAL EMISSIONS:

Verify and correct, if necessary, the tons per year emissions contained in the air permit application.

Response:

The only correction required is to the Lead emissions as explained in Section 1, page I-19 of this Supplemental Report. Table 4-1 from *Vol. I - Application is included herewith as Exhibit III-1 on page III-2 of this Section III of the Supplemental Report.

---

*Palm Beach County, Florida Solid Waste Resource Recovery Facility Application for Power Plant Site Certification dated April, 1985.

EXHIBIT III - I

TABLE 4-1 (Revised as of October 18, 1985)

CONTROLLED EMISSION FACTORS DEVELOPMENT FOR RDF FIRED SPREADER STOKER FURNACES

(ANNUAL AVERAGE BASED ON 1800 TPD RDF FIRED)

POLLUTANT	LBS/TON RDF	LBS/HR	TONS/YEAR	GM/SEC @ 1800 TPD	G /SEC @ 2100 TPD
CARBON MONOXIDE	12.0	900.	3942.	113.	132
NITROGEN DIOXIDE	4.0	300.	1314.	37.8	44.1
SULFUR DIOXIDE	9.0	675.	2957.	85.1	99.3
CHLORIDES	3.5	263.	1150.	33.1	38.6
VOLATILE ORGANIC COMPOUNDS	.20	15.0	65.6	1.89	2.21
PARTICULATE MATTER	.65	48.8	214.	6.14	7.16
SULFURIC ACID MIST	.0004	.030	.131	.0038	.0044
FLOURIDES	.04	3.00	13.2	.38	.44
LEAD	.014	1.05	4.6	.132	.154
MERCURY	.003	.225	.98	.0284	.0331
BERYLLIUM	9.0 E-06	6.8 E-04	3.0 E-03	8.5 E-05	9.9E-5
2,3,7,8-TCDD	8.5 E-08	6.4 E-06	2.8 E-05	8.0 E-07	9.3E-7

QUESTION NO. 9 - ON AIR QUALITY RECEPTORS:

Tables 5-9 A through F of appendix 10.1.5 contain results of the highest, second high modeled concentrations for the proposed facility. These results include values at a distance of 730 meters from the center of the facility. The modeled runs, however, do not include any receptors at this distance. Please explain.

Response:

It is noted in Vol. IV - Air Quality, Appendix 10.1.5 on Prevention of Significant Deterioration, page 56, paragraph 5.6 of the Report on Air Quality Impacts Analysis, (Revised March, 1985) that a series of computer runs were made for screening purposes. The results of these runs were not documented other than to note that (5.6.1) maximum impacts were identified at distances of 571, 926, 1046 and 1615 meters from the proposed source based on atmospheric stability.

An initial series of runs of the ISCST and ISCLT models were made for 26 concentric rings distances from the source for every 6° azimuth. The closest rings were those indicated above as distances of maximum impact based on the screening model. These runs did not, however, include the closest boundary distance of 730 meters. The results of these runs have been compiled and submitted to the FDER. At the suggestion of the FDER, a second series of computations were made specifically, to develop the impacts at 730 meters (<u>closest</u> point of the source to its boundary line). These data were not documented in appendices because of the massive paper volume, but rather, the outputs were used by the computer to create the tabular listings of Tables 5-9A through F <u>directly</u>. The closest boundary line ring of 730 meters was also used in the model runs that included three (3) existing local sources. These data were restricted azimuth intervals in 1° increments ± 5° downwind of the source on centerline bearing over the proposed facility. These data were made available in the complete Appendices.

QUESTION NO. 10 - ON TECHNICAL & ADMINISTRATIVE REVIEW PROTOCOL:

EPA informed us very recently that The Power Plant Act is not totally compatable with their rules and they are going to rescind our delegation of sources subject to PSD PPS. The county needs to be informed of such and they must send a letter to me requesting that we perform the Technical and Administrative review for EPA so that they can issue a federal PSD permit.

Response:

Palm Beach County Solid Waste Authority is pleased to have the State of Florida Department of Environmental Regulation (FDER) perform the Technical and Administrative review of our Application. As requested, Authority Executive Director, Tim Hunt, Jr. will request this review in a letter to be addressed to the attention of Clair Fancy of the FDER.

SECTION IV

RESPONSE TO

NATIONAL PARK SERVICE REVIEW

SECTION IV

RESPONSE TO

NATIONAL PARK SERVICE

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SECTION IV

RESPONSE TO

NATIONAL PARK SERVICE

List of Exhibits

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RESPONSE TO
NATIONAL PARK SERVICE REVIEW

1. AIR QUALITY IMPACT

It is noted that the proposed facility is not mass burn but controlled burn of refuse derived fuel (RDF) in spreader stoker furnaces. Refuse will be prescreened for salvage material including metals. The project will have an ultimate design capacity for combusting 2100 TPD RDF, with an initial installation of two (2) 700 TPD furnace/boiler systems.

The suggested application of emission standards developed for the stagnant atmospheric conditions prevalent for the State of California to the well ventilated lower east coast of Florida may not be appropriate. Air pollution potential studies over a three to six year period (Zimmerman J. Forecasting Air Pollution Potential, Meteorological Aspects of Air Pollution, TRAINING COURSE MANUAL in AIR POLLUTION, 411, Feb. 1969 Revised.) have shown most of Florida, including Palm Beach County to have a zero potential for advisory days of high air pollution. Mean morning and afternoon mixing heights are estimated at 800 and 1375 meters respectively for Palm Beach as compared to 600 and 800 meters for coastal California (Holtzman, G.C. Mixing Heights, Wind Speeds and Potential for Urban Air Pollution Throughout the Contiguous United States, AP-101 NTIS:PB207103, 1972). The region is not subject to recirculation but rather, prevailing easterly winds. With respect to projected impacts from the proposed source on the Everglades National Park, it is noted that the park is southwest of the source at a distance of 120 km at its closest point. The 5-year average frequency northeast wind (required for impaction) is 4.17% with an annual average speed of 5.7 m/s. For impaction to occur therefore, steady state winds and stability would have to persist for more than 6 consecutive hours. The total percentage of northeast winds with stability classes 5 and 6 would represent less than 53 hours/year.

1.1 Ozone Levels

With relation to ozone levels, it has been noted in Volume I-Application, Chapter 2, Table 2.3-13, that if all the VOC from the proposed facility were converted to e.c. ozone, the highest second highest impact would be 3 ug/m^3 or less than 1.3% of the Air Quality Standard of 235 ug/m^3 and this impact would be within the facility boundaries.

1.2 Visibility

A visibility screening analysis has been performed based on the instructions for Level-1 Screening Analysis, as available in Latimer and Ireson, Workbook for Estimating Visibility Impairment, Draft, July 1980. The absolute values of the contrast parameters obtained were significantly less then the critical level of 0.1 for the distance of 120 km from the proposed facility (see Exhibit I).

1.3 SO_2 Impact

Annual impact analyses for SO_2 at a distance of about 53.7 km were less than 0.12 ug/m^3 for winds from an 048 - 036° sector. This represents approximately 10% of the concentration level considered as significant.

Projected impacts of SO_2 from the proposed facility on the Everglades National Park at a distance of 120 km on a bearing line of 228° were calculated assuming an exponential decrease in concentration with an exponential increase in downwind distance. For combined sources, a similar impact can be generated with the same assumption but based on impact concentrations at a distance of 9.796 km bearing 232° and 24.563 km bearing 249°, assuming these locations are in-line. The results of these analyses are presented in EXHIBIT II.

The highest projected impacts from the proposed facility are only 3.6%, 12.4% and 17.8% of the EPA designated significant impact levels for annual, HSH 24-hour and HSH 3-hour averaging periods respectively.

EXHIBIT I

```
   SCREENING ANALYSIS
 VISIBILITY LEVEL ONE


 DIST. TO LVL. I AREA
         120.      KM
 BCKGND VISUAL RANGE
          40.      KM
 SIGMA Z AT STAB: F
         100.       M
 MASS EMISSIONS: MTPD
        0.531    QPAR
        3.265    QNOX
        7.348    QSO2

 OPTICAL THICKNESS:
      0.00885    PART
      0.00925     NO2
      0.00431    ASOL

 CONTRAST PARAMETER:
    -0.000883    CSKY
    -0.000008    CTER
     0.001581    CS/T
```

EXHIBIT II

SULFUR DIOXIDE

PROJECTED IMPACT ON EVERGLADES NATIONAL PARK

(Bearing 228°, 120 km)

		CONCENTRATION (ug/m3)				CONTRIB. OF RDF %
				PROPOSED RDF & EXISTING		
YEAR	AVERAGING TIME	SIGNIF. IMPACT	MAX. PSD[1]	RDF[2]	SOURCES[2]	
1970	HSH 3-HR	25	25	2.78	43.0	6.5
	HSH 24-HR	5	5	0.33	7.7	4.4
	ANNUAL	1	2	0.025	2.3	1.1
1971	HSH 3-HR	25	25	4.46	17.3	25.7
	HSH 24-HR	5	5	0.58	18.1	3.2
	ANNUAL	1	2	0.023	1.6	1.4
1972	HSH 3-HR	25	25	2.96	8.2	36.2
	HSH 24-HR	5	5	0.55	5.9	9.4
	ANNUAL	1	2	0.036	1.8	2.0
1973	HSH 3-HR	25	25	2.70	11.2	24.1
	HSH 24-HR	5	5	0.35	4.8	7.3
	ANNUAL	1	2	0.023	1.8	1.3
1974	HSH 3-HR	25	25	0.89	1.6	56.9
	HSH 24-HR	5	5	0.62	3.7	16.7
	ANNUAL	1	2	0.028	1.8	1.5

NOTE 1 : Class I

NOTE 2 : Based exponential decay of concentration with downwind exponential increase of distance.

On the basis of these analyses, the proposed RDF source cannot be considered significant relative to the projected impact of sources already in existence.

2. BEST AVAILABLE CONTROL TECHNOLOGY ANALYSIS

Best Available Control Technology (BACT) analysis and the related issues of pollutant emissions are covered in the following Sections of this Supplemental Report:

Section I	Emission Factors
Section II	Best Available Control Technology

3. COMPARATIVE EMISSIONS FOR PALM BEACH AND BROWARD COUNTIES

Emission Factors for the proposed 3300 TPD mass burn facility for Broward County and the 1800 TPD RDF (annual average for ultimate design) plant at Palm Beach are derived from the Tons per Year emissions of pollutants from the listing given in the National Park Service review of the Palm Beach County Solid Waste Authority Power Plant Site Certification Application. These derived Emission Factors are displayed as follows:

	Emission Factors (lb/ton)	
	Palm Beach	Broward
SO_2	9	5.7
NO_x	4	5.8
CO	12	0.92
PM	0.65	0.76
Lead	0.0014	0.3105
Flourides	0.0400	0.2590
Sulfuric Acid Mist	0.0004	0.0287

The Palm Beach Emission Factors for the pollutants listed are in agreement with the Emission Factors given in Table 4-1 of Reference "F". (See Section I, page I-1 of this Supplemental Report). With the exception of the Emission Factor for Lead, they are to remain unchanged. (See Section I, page I-19 for discussion of proposed revision to Lead Emission Factor).

A discussion of the Emission Factors of Palm Beach relative to those of interest to the National Park Service follows:

3.1 SO_2 Emission Factors

3.1.1 Palm Beach RDF System

Basis for the Palm Beach County SO_2 Emission Factor of 9.0 lb/ton is given in Section I, page I-14 of this Supplemental Report. The 9.0 lb/ton factor assumes all of the sulfur in the RDF fuel is completely converted to SO_2.

3.1.2 Broward Mass Burn System

In general, the SO_2 emissions data base for mass burn waterwall facilities indicates lower emissions relative to RDF systems. This is attributed to more of the sulfur in the refuse fuel remaining in the bottom ash instead of being converted to SO_2 stack emissions. Accordingly the 5.7 lb/ton Emission Factor for the proposed Broward County mass burn facility appears reasonable relative to the 9.0 lb/ton Emission Factor for the Palm Beach RDF spreader stoker plant.

3.2 NO_x Emission Factors

3.2.1 Palm Beach RDF System

Basis for the Palm Beach County NO_x Emission Factor of 4.0 lb/ton is given in Section I, pae I-17 of this Supplemental Report. The

NO_x Emission Factor is derived from th RDF Fired Spreader Stoker emission rates given in Exhibit 4-5, page I-18 taken from Reference "A".

3.2.2 Broward Mass Burn System

In like manner, the NO_x Emission Factor for the Broward Mass Burn system may be derived from the mass burn waterwall emission rates, also given in Exhibit 4-5, as follows:

UNCONTROLLED NO_X EMISSION IN LB/1.0E6 BTU = 0.07 TO 0.42

Assuming 4,500 BTU/LB for Refuse, Convert LB/1.0E6 to LB/Ton

0.07 LB/1.0E6 BTU x 4,500 BTU/LB x 2,000 LB/Ton = 0.63 LB/Ton
0.42 LB/1.0E6 BTU x 4,500 BTU/LB x 2,000 LB/Ton = 3.78 LB/Ton

Therefore,

Uncontrolled Total NO_x Emission in LB/Ton = 0.63 to 3.78

The 5.8 LB/Ton Emission Factor proposed by Broward is a conservative overstatement of the emission levels that may be expected based on the data given in Exhibit 4-5 for the mass burn waterwall system.

3.3 CO Emission Factors

3.3.1 Palm Beach RDF System

Basis for the Palm Beach County CO Emission Factor of 12 lb/ton is given in Section I, pages I-6 and I-7 of this Supplemental Report.

3.3.2 Broward Mass Burn System

CO Emission Factors reported in the literature are generally, but not always, lower for mass burn systems relative to RDF. Exhibit III, taken from a recently published paper, illustrates some of the variations for stack tests performed at two RDF facilities (Hamilton and Albany) and two mass burn facilities (Chicago and Hampton). The exhibit shows that CO emissions is sensitive to 0_2 concentrations, indicative of excess air variations. The Hampton II and III tests indicate that a wide divergence of CO emissions performance is possible on a mass burn system, shown in Exhibit III to be sensitive to 0_2 concentrations. The Albany and Hampton III coinciding plot of test data illustrates that equally good CO emissions performance can be obtained with RDF and mass burn systems when proper combustion and air supply conditions are maintained.

In order to estimate a CO Emission Factor that may be appropriate for the Broward mass burn waterwall facility, reference is made to Exhibit 4-3.1 (Section I, page I-8), where the following is noted:

Uncontrolled CO Emission in LB/1.0E6 BTU = 0.15 to 2.0

Assuming 4500 BTU/LB for Refuse, convert LB/1.0E6 to LB/Ton

0.15 LB/1.0E6 BTU x 4500 BTU/LB x 2000 LB/Ton = 1.35 LB/Ton
2.0 LB/1.0E6 BTU x 4500 BTU/LB x 2000 LB/Ton = 18.00 LB/Ton

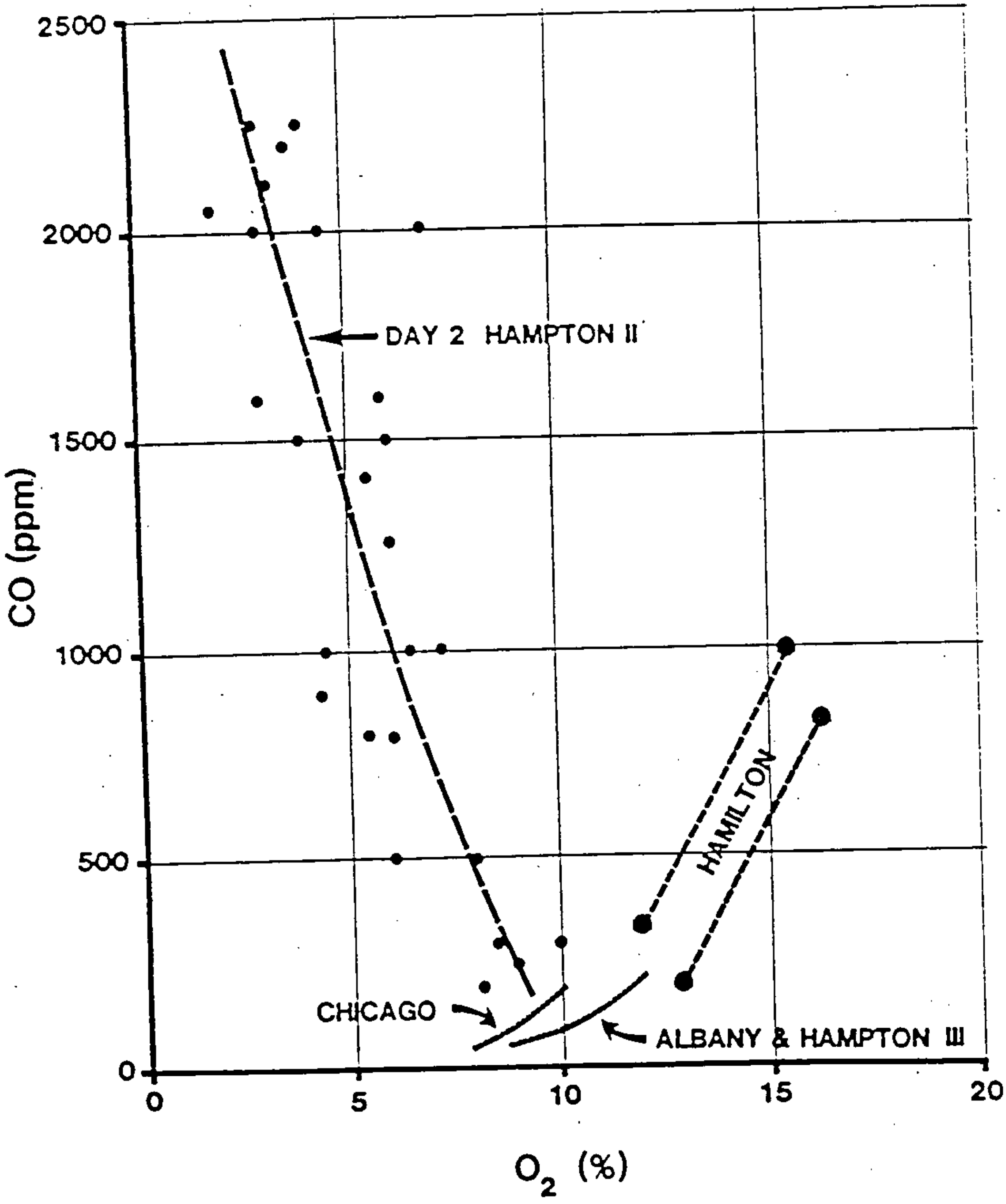
Therefore

Uncontrolled Total CO Emission in LB/Ton = 1.35 to 18.00

Whereas the 0.92 lb/ton Emission Factor (equivalent to 73 ppm) for CO emissions proposed by Broward County appears low, nevertheless this level of performance has been achieved under optimum

EXHIBIT III

CARBON MONOXIDE AND OXYGEN IN EMISSIONS FROM FIVE STACK TESTS



Source: "Best Available Control Technology For Polychlorinated Dibenzo-P-Dioxins And Polychlorinated Dibenzo-P-Furans from Municipal Waste Combustion" F. Hasselriis October, 1985 conditions of operation. See Exhibit III of this Section IV and also Exhibit 4-3.2 on page I-9 of Section I.

3.4 PM Emission Factors

3.4.1 Palm Beach RDF System

Basis for the Palm Beach County PM Emission Factor of 0.65 lb/ton is given in Section I, page I-2 of this Supplemental Report. The PM Emission Factor of 0.65 lb/ton derived from the RDF Fired Spreader Stoker emission rates given in Exhibit 4-1, page I-3 taken from Reference "A".

3.4.2 Broward Mass Burn System

In similar fashion, the PM Emission Factor for the Broward Mass Burn system may be derived from the mass burn waterwall emission rates, also given in Exhibit 4-1 as follows:

ASSUME THE BROWARD COUNTY AIR POLLUTION CONTROL SYSTEM WILL COLLECT SUFFICIENT PM SO AS NOT TO EXCEED A GUARANTEED GRAIN LOADING OF 0.03 GRAINS/DSCF AT 12% CO_2. THIS EMISSION LEVEL IS PRESUMED TO REPRESENT BACT FOR TSP.

FROM REFERENCE "A", TABLE 29, (EXHIBIT 4-1) UNDER MASS BURNING WATERWALL SYSTEMS,

UNCONTROLLED PM EMISSION IN GRAINS/DSCF, 12% CO_2 = 0.83 TO 2.05 = 1.44 (AVERAGE); % REMOVAL EFF. TO OBTAIN 0.03 GR/DSCF ASSUMING GRAIN LOADING OF 1.75 GR/DSCF = $100\left(1 - \frac{0.03}{1.75}\right) = 98.3\%$

UNCONTROLLED PM EMISSION IN LB/1.0E6 BTU = 1.27 TO 7.32 = 4.30 (AVERAGE)

EXHIBIT IV

State demands new controls for incinerator

By ANDREW FROMAN
Herald Staff Writer

FORT LAUDERDALE — State environmental officials want Broward County to install tougher pollution controls on its first garbage-burning resource recovery plant, a move that could raise the plant's operating cost $2.4 million a year.

The improvements could add more than $40 million — about $2 a year for every person in Broward County — to the cost of operating the $187 million plant over its expected 20-year life.

But Tom Henderson, the director of the county's resource recovery program, said the state's recommendations are based in part on inaccurate information from his office. He hopes to convince the state that additional pollution controls aren't necessary.

County officials intend to build two resource recovery plants at a total cost of $521 million. If operating costs are higher than expected, garbage rates will be increased.

"You have to swallow the price because the price of continuing to endanger the water aquifer (with landfills) is too high," said County Commissioner Nicki Grossman.

State officials said their recommendations are based on research of air pollution controls at plants in California, New York and New Jersey.

"The technology in resource recovery has really come along a lot further a lot faster than many other areas. It seems people are always finding improvements," said Clair Fancy, deputy director of the Florida Department of Environmental Regulation's Bureau of Air Quality Management.

Fancy said Broward should be able to lower hydrogen fluoride, sulphuric acid mist and lead emissions by using larger or additional pollution controls.

If the DER's recommendations are accepted by Gov. Bob Graham and the Cabinet, which issues construction permits for resource recovery plants, the new equipment would have to be installed before the first load of garbage is burned.

Operating the equipment would raise the cost of burning garbage by $2 a ton or $6,600 a day for the 3,300 tons of garbage to be processed every day at the county's first plant at U.S. 441 and State Road 84.

Henderson hopes to convince the state that the additional equipment isn't necessary. He said the DER's recommendations are based in part on inaccurate information supplied by his office in March. Lead emissions would be .027 pounds for each ton of refuse burned, not .27 pounds as estimated. A decimal point was misplaced, he said.

Since lead emissions will be only one-tenth as high as originally estimated, there might not be a need for additional pollution controls, Henderson said.

FROM H W PALM BEACH P. 1

10.16.1985 13:39

We would expect the Palm Beach Lead Emission Factor to be about one-half of the Broward Lead Emission Factor. This is due to the removal of the lead contained in the RDF rejects which thereby reduces the concentration of lead in the RDF that is to be combusted in the proposed Palm Beach RDF spreader stoker furnace/boiler systems.

To illustrate the basis for the statement that lead emissions for the RDF combustion system would be about one-half that of the mass burn system and of the order of magnitudes given above, reference is made to paragraph 3.4 above on PM Emission Factors for Palm Beach RDF and Broward mass burn systems and also to Exhibit 4-6.4, page I-23, Section I of this Supplemental Report.

From paragraph 3.4, PM Emission Factors are as follows:

Palm Beach RDF System - 0.65 lb/ton

Broward Mass Burn System - 0.76 lb/ton

From Exhibit 4-6.4, Lead concentrations in controlled particulate emissions for RDF (Category III) and mass burn (Category II) systems are given as follows:

RDF System: 4,470 - 18,400 ppm

Mass Burn System: 18,100 - 34,200 ppm

Assuming lead concentrations on PM to be at the upper ends of the respective ranges shown for RDF and mass burn systems, the Lead Emission Factors are then derived as follows:

Palm Beach RDF System

0.65 lb/ton x 18,400 ppm = 0.012 lb/ton.

Broward Mass Burn System

0.76 lb/ton x 34,200 ppm = 0.026 lb/ton

The Lead Emission Factors derived above are in good areement with Lead Emission Factors now proposed.

3.6 Fluoride Emission Factors

3.6.1 Palm Beach RDF System

Basis for the Palm Beach County Fluoride (HF) Emission Factor of 0.040 is given in Section I, page I-36 of this Supplemental Report.

3.6.2 Broward Mass Burn System

From Reference "B", page 292 (EXHIBIT V) provides the data base for estimating the Fluoride (HF) Emission Factor for the Broward Mass Burn System. Exhibit IV suggest a Fluoride Emission Factor of 0.06 lb/ton whereas Broward chose a more conservative Factor of 0.259 lb/ton.

3.7 Sulfuric Acid Mist Emission Factors

3.7.1 Palm Beach RDF System

Basis for the Palm Beach County Sulfuric Acid Mist Emission Factor of 0.0004 is given in Section I, page I-38 of this Supplemental Report.

3.7.2 Broward Mass Burn System

Because Sulfuric Acid Mist emissions derive from SO_2 emissions and

EXHIBIT V

TABLE 10 FLUORIDE EMISSIONS

Incinerator	ppm	Ref.
Oberhausen	20*	15
Bernion	4.8	31
Braintree	2.8	4
Boston	5	12
Zurich	18	7
Dusseldorf	10	7
Average	6.4	
Std. Dev.	5.91	

*Corrected to 12% CO_2

Based on these data 6.5 ppm or 0.06 lb/ton (0.03 kg/Mg) has been chosen as a conservative estimate of fluoride emissions.

CONTROLS

Fluoride emission control is normally not required on municipal incinerators except in conjunction with acid gas control. Some of the fluoride appears to be associated with the particulate matter and therefore will be removed by the particulate control device while some is apparently present as a gas and would be removed in the acid gas scrubber. Very little fluoride removal data are available but it appears that the fluoride may be removed a little more efficently than the hydrochloric acid.

TRACE METALS, LEAD, MERCURY, BERYLLIUM

EMISSIONS

Some of the lead in the municipal waste is emitted with the fly ash from a municipal incinerator. The amount of lead emitted will depend upon the efficiency of the particulate control system. Some reported values of lead emissions for incinerators using electrostatic precipitators for particulate control are shown in Table 11. We have chosen 34,200 μg/g (0.034 lb/lb) of particulates or 0.012 lb/ton (0.006 kg/Mg) of refuse burned as a reasonable estimate of the lead emissions.

TABLE 11 LEAD EMISSIONS

Incinerator	μg Pb / g of Particulates	gr/dscf	mg / dscm	Ref.
Braintree		0.0026	(5.9)	4
Washington, D.C.	78,000			36
Various	18,100-34,200			1
Hamilton	5,700			6
German	20,100			6
Average	31,200			
Std. Dev.	29,700			

Trace amounts of mercury have been found in the emissions for municipal incinerators. Values reported in the literature are shown in Table 12. Based on the listed data, an emission of 2.4×10^{-4} gr/dscf (0.55 mg/dscm) or 0.0064 lb/ton (0.0032 kg/Mg) of refuse burned was chosen as a conservative estimate of total mercury emissions.

TABLE 12 MERCURY EMISSIONS

Incinerator	μg Hg / g of Particulates	gr/dscf	mg / dscm	Ref.
Braintree		6.1×10^{-6} particulate	(.014)	4
		2.4×10^{-4} vapor	(.55)	
Hamilton	300			6
Germany	133			6
Gent, Belgium		6.0×10^{-5} vapor	(.014)	37
Average	216	1.6×10^{-4}	(.037)	

Few data giving emissions of beryllium from municipal incinerators were found. The only reference to beryllium emissions was for the Braintree incinerator [4] where less than 0.15 μg/g of emitted particulates was reported. Using this data, based on the particulate emissions previously cited, the emissions of beryllium are estimated to be less than 5.6×10^{-8} lb/ton (2.8×10^{-8} kg/Mg) of refuse burned.

Trace quantities of a large number of other metals have been found in the fly ash from municipal incinerators. Most of them are present in very small quantities and are of little environmental concern. Concentrations of the more toxic metals are presented in Table 13.

CONTROLS

The trace metals are minor and variable constituents of the waste. Most of the metals except for mercury appear to concentrate in the bottom ash or fly ash. Data presented by Law [38], factored for the difference in efficiency between a baffle chamber and and ESP (95 percent), indicate that most of the mercury is emitted, less than 3 percent of the volatile metals (such as lead, cadmium and zinc) are emitted and less than 1 percent of the nonvolatile metals (such as barium, chromium, and copper) are emitted.

The data indicate that an effective particulate control system is about equally effective in controlling the trace metals. It is sometimes stated that a fabric filter's high efficiency for fine particulates makes it more efficient than other devices in collecting trace metals, but there is inadequate data to substantiate such superiority.

since the Palm Beach RDF SO_2 Emission Factor is 9 lb/ton relative to the Broward Masss Burn SO_2 Emission Factor of 5.7 lb/ton, as developed in paragraph 3.1 above, we would expect a proportional decrease in the Sulfuric Acid Mist Emission Factor for the Broward Mass Burn system relative to that for the Palm Beach RDF system.

This would be calculated as follows:

SULFURIC ACID MIST
EMISSION FACTOR

$$= \frac{\text{5.7 LB/TON (BROWARD } SO_2 \text{ FACTOR)}}{\text{9.0 LB/TON (PALM BEACH } SO_2 \text{ FACTOR)}}$$

$$\times \text{ 0.0004 LB/TON (PALM BEACH } H_2SO_4 \text{ FACTOR)}$$

$$= \text{0.00025 LB/TON (BROWARD } H_2SO_4 \text{ FACTOR)}$$

Our 0.00025 lb/ton estimate for the Broward Sulfuric Acid Mist Emission Factor is approximately one-hundredth of the 0.0237 lb/ton prediction (shown in the tabulation on page IV-6) derived from the tons per year data for Broward's Sulfuric Acid Mist emissions provided in the National Park Service Technical Review.

The boiling point of sulfuric acid is 626°F. At the stack exit gas temperature of 450°F, the sulfuric acid that is formed from SO_2, H_2O and O_2 would be an acid liquid aerosol. The acid liquid aerosol that is not absorbed on fly ash particulate and collected in the electrostatic precipitator would pass into the stack. In order to determine sulfuric acid mist emissions, the stack gases would be isokinetically sampled. As the sampled gas/aerosol mixture is drawn through the sampling nozzle and passes through the sampling train, the gas/aerosol mixture is cooled and additional sulfuric acid is formed from the SO_2, O_2 and H_2O in the gas stream, with the already-formed sulfuric acid aerosol possibly acting as a seed. The quantity of sulfuric acid transformed from SO_2, O_2 and H_2O in the sampling train may far exceed the sulfuric acid already formed before the sampled gas/aerosol mixture passed into the sampling nozzle. Thus the sulfuric acid concentration, as determined by analyzing the sulfuric acid in collection flasks of the sampling train, may not be representative of the concentration of sulfuric acid in the gas stream at the sampling nozzle. In-situ measurements of SO_2 and O_2 at the sampling nozzle locations may be used to correct and adjust for sulfuric acid formation in the sampling train, but it is not clear from the test data available if these corrections/adjustments were in fact part of the test sampling protocol. If they were not, the reported test results would necessarily be suspect as to its validity

The chemistry of SO_2 precipitation to sulfuric acid mist is a complex, highly variable process whether the precipitation occurs within the plant furnace/boiler/air pollution control system, in a stack test sampling train or in the atmosphere (the "acid rain" phenomenon). Researchers in this field have shown wide divergence in findings and predictions. The second order of magnitude disparity between Emission Factor estimates made for Palm Beach and Broward County may indeed be considered good agreement in view of the present constraints on "state-of-the-art" comprehension of the subject.

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EMISSIONS AND EMISSION CONTROL IN MODERN MUNICIPAL INCINERATORS

WILBERT L. O'CONNELL, G. CHRIS STOTLER, and RONALD CLARK
Battelle's Columbus Laboratories
Columbus, Ohio

ABSTRACT

This paper presents a compilation of data on the mass burning of municipal wastes in waterwall incinerators. Emissions data from the literature are presented, with emphasis on typical emission rates for modern incinerators. The typical emission rates presented will be useful for predicting the expected emissions and environmental impacts of proposed minicipal incinerators, thereby aiding in the determination of the applicability of various regulations and the necessity for the installation of control equipment. Control technology is briefly reviewed with emphasis on the best control technology available to reduce emissions which may be cited by regulatory authorities to set the Lowest Achievable Emission Rate (LAER), or the Best Available Control Technology (BACT).

INTRODUCTION

The incineration of municipal solid waste generates a number of air pollutants including particulate matter, hydrogen chloride, oxides of nitrogen and sulfur, carbon monoxide, hydrocarbons and small to trace quantities of many other materials. Battelle has compiled the emissions reported for a number of municipal incinerators. These data, for the most part, represent the emissions from incinerators mass-burning municipal refuse on a grate in a waterwall furnace using an electrostatic precipitator (ESP) for emissions control – Rinaldi's [1] category II incinerator – although other types are occasionally cited. In general, there was no attempt to screen referenced data for adequacy or completeness. If sufficient data were available to convert the reported data to standard forms comparable with other presented data, the conversion was made; if not, the data are presented as reported in the original reference. The reader can then, if he chooses, make use of these data by applying "average" conversion factors with full knowledge of the probable accuracy of such a conversion. With these data, Battelle has used its best engineering judgement to make reasonably conservative estimates of the emissions from a modern waterwall municipal incinerator which may be used during the preliminary design and permitting activities to predict the emissions from a proposed incinerator and to aid in determining the applicability of various regulations and the necessity for installing control equipment.

Municipal incinerators are normally located near metropolitan areas to minimize the costs of waste transportation. Unfortunately, these areas are frequently "nonattainment" for at least one of the air pollutants for which the incinerator is a major source (normally SO_2, NO_x, CO, and Particulates), thus forcing the incinerator operator to consider both the Emissions Offset Ruling, and Prevention of Significant Deterioration (PSD) regulations when applying for an air pollution permit.

Major facilities locating within nonattainment areas are required by the Emissions Offset Interpretive Ruling (40 CFR 51 Appendix S) to meet the Lowest Achievable Emission Rate (LAER) for those pollutants, for which the area is nonattainment, which are emitted in significant quantities. (Refer to Table 1.) LAER is defined as the lowest of the most stringent limitation contained in any state implementation plan unless it can be shown to be unattainable or, the most stringent emission limitation achieved in practice by such category of source.

TABLE 1 SIGNIFICANT QUANTITIES FOR PSD AND EPA EMISSION OFFSET RULING

Pollutant	Quantity, Ton/yr
Carbon Monoxide	100
Nitrogen Oxides	40
Sulfur Dioxide	40
Particulates	25
Ozone	40
Lead	0.6
Asbestos	0.007
Beryllium	0.0004
Mercury	0.1
Vinyl Chloride	1
Fluorides	3
Sulfuric Acid Mist	7
Hydrogen Sulfide	10
Total Reduced Sulfur	10

Large incinerators, emitting over 100 tons (90 Mg) per year of a regulated pollutant, and constructed in an area which is an attainment area for some pollutants, are required by the PSD regulations to install the best available control technology (BACT) for each pollutant that is subject to regulation and which is emitted in significant quantities. BACT is defined as an emission limitation based on the maximum degree of reduction of each pollutant achievable for such source through application of available techniques taking into account energy, environmental and economic impacts, and other costs.

LAER can be established by the transfer of control technology from another class of source or from pilot tests if feasible [2]. As of early 1981, there was no record in EPA's LAER clearinghouse of any determination of LAER for a municipal incinerator; however, it is not mandatory that the clearinghouse be notified of such a determination.

To derive emission factors from the commonly reported pollutant concentrations in the stack gas, it is necessary to relate the flue gas flow rate to the waste burning rate. Flue gas flow rates from mass-burning municipal incinerators reported in the literature are shown in Table 2.

TABLE 2. FLUE GAS RATES

Incinerator	Kg DFG / Kg feed	dscfm / Tph	dscm / Mg feed	% CO_2	Ref.
Harrisburg	5.89	2760	(5160)	9.3	3
Braintree		2440	(4550)	6.7	4
Chicago NW	6.180	2760	(5170)	9.6	5
Average		2650	(4950)	8.5	

An arbitrary conservative bias of about 15 percent has been built into all emission factor calculations by the choice of a flue gas rate of 3,000 dscfm/tph of feed (5,600 dscm/Mg). This rate was assumed to correspond to an 8 percent CO_2 concentration in the stack gas for the purpose of correcting the emissions to 12 percent CO_2 where required.

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PARTICULATES

EMISSIONS

Particulate emissions reported in the literature for mass-burning municipal incinerators using electrostatic precipitators for particulate control are shown in Table 3 and Table 4. The federal new source performance standard for municipal incinerators is 0.08 gr/dscf (180 mg/dscm*) corrected to 12 percent CO_2; however, considering the trends in emissions control requirements over the past several years and recent bids by equipment vendors, a controlled particulate loading of 0.020 gr/dscf (46 mg/dscm) corrected to 12 percent CO_2 was selected as being, in our best engineering judgement, the lowest emission level that can be reliably obtained by a state-of-the-art electrostatic precipitator over the long term. It was also the lowest value that equipment vendors were willing to guarantee for a long period of time in a recent procurement; however, lower values could be guaranteed on a one time, new equipment performance test basis [17, 18]. On this basis, the incinerator will have a particulate emission rate of 0.34 lb/ton (0.17 kg/Mg).

CONTROLS

Maryland appears to have the most stringent emission limitation in the U.S. at 0.03 gr/dscf (69 mg/dscm) corrected to 12 percent CO_2, but in this

---

*Dry standard cubic meter.

TABLE 3 UNCONTROLLED PARTICULATE EMISSIONS AND ESP EFFICIENCIES FOR MUNICIPAL INCINERATORS

Incinerator	Uncontrolled gr/dscf @ 12% CO_2 (lb/Ton)	Controlled gr/dscf @ 12% CO_2 (lb/Ton)	ESP Eff	Ref.
Harrisburg #1	1.14-2.08	0.058-.089	94.9-95.7	6
"	1.132-2.602 av 1.733 (15)	0.039-.083 av 0.0559	96.8	3
Harrisburg #2	1.14-2.62	0.046-.089	96.0-96.6	6
"	1.134-2.056 av 1.461	0.053-.084 av 0.069	95.3	3
Chicago NW	0.613-1.26 av 1.06	0.027-.0634 av 0.0384	96.4	5
	(23.4)	(0.55-1.15 av 0.788)	96.6	5
	(37.2)	—		1
Braintree	0.866-1.126 av 0.973	0.221-.256 av 0.236	73.0	4
	(7.7-14.2 av 10.9)	(2.3-3.4 av 2.7)	75.2	4
	(15.3)			1
Various European	3.38-9.75			7
Various	(30)			8
Nashville	1.196	0.024	98.0	6
	1.406	0.0073	99.5	
	1.141	0.0211	98.2	

gr/dscf x 2289 = mg/m^3
lb/Ton x 0.5 = Kg/Mg

TABLE 4 CONTROLLED PARTICULATE EMISSIONS FROM MUNICIPAL INCINERATORS

Incinerator	Control	Year	gr/acf	Mg/acm
Baltimore 4	ESP*	76	$.025^{b,9}$	57
Braintree	"		$.108^{10}$, $.2^{b,11}$	247,460
Brooklyn SW	"		$.073^{b,12}$, $.015^{c,10}$	160,34
Chicago NW	"	71-75	$.03^{b,10}$, $.0229^{10}$, $.0384^{b,5}$	70,52.4,87.9
			$.05^{b,11}$	100
Dade Co. NE	"		$.0272^{c,10}$	62.3
E. Bridgewater	FF**	75	$.024^{b,9}$	55
Hamilton	ESP		$.682^{b,13}$	1560
Harrisburg	"	73	$.040^{10}$, $.045^{10}$, $.07^{b,11}$	91, 104, 200
Lexington	"		$.050^{b}$	110
Montreal	"	70-71	$.0133^{10}$, $.0799^{10}$	30.4, 183
Nashville	"	76	$.0182^{b,9}$, $.0175^{b,14}$, $.0243^{b,14}$	41.7, 40.1, 55.6
Neuchatel, Switzerland	FF		$.05^{b}$	100
N.Y. South Shore	ESP		$.055^{c,10}$	129
Norfolk	"	76	$.05^{b,9}$, $.05^{b,11}$, $.029^{b,6}$	100, 100, 66
Oberhausen	"		$.0562^{b,15}$	129
Oceanside	"		$.045^{b,10}$, $.3^{b,10}$	100, 69
Ogden	"	74	$.045^{b,9}$	100
Philadelphia EC	"	77	$.047^{b,9}$	110
Philadelphia NW	"	76-79	$.048^{b,9}$, $.0168^{10}$, $.0247^{10}$,	110, 39, 57
			$.04^{b,16}$, $.05^{b,16}$	90, 100
Quebec	"	70	$.095^{a,10}$	220
Saugus	"	76	$.049^{b,9}$, $.025^{b,11}$	110, 57, 62
Washington, D.C.	"	73	$.04^{b,9}$, $.0578^{a,10}$	90, 132

(a) dry specified
(b) dry and 12 percent CO_2 specified
(c) 50 percent EA specified

* electrostatic precipator
** fabric filter

case, it does not appear to set LAER as several incinerators have reported lower emissions. The lowest emission from a commercial incinerator that has been found to date is 0.018 gr/dscf (41 mg/dscm) corrected to 12 percent CO_2 reported for Nashville Thermal Transfer Unit 2 in 1977 [14]. This unit used a three-field electrostatic precipitator for particulate control.

Fabric filters are sometimes represented by regulating agencies as the technology that will allow incinerators to obtain particulate emissions below 0.01 gr/dscf corrected to 12 percent CO_2. We have conducted an extensive search for reports of the performance of fabric filters on municipal incinerators and were able to find only the following six pilot and two operating performance test reports. Deficiencies in some of the data and variations in operating procedures between tests make it difficult to compare the data and draw any general conclusions, however, all of the data obtained are reported to illustrate the extent of the data base.

1. Several short-term pilot tests of several types of fabric filter bags conducted at the Nashville incinerator in 1977 [19] gave emissions, apparently determined with a cascade impactor, of less than 0.001 gr/dscf (2.3 mg/dscm) at 12.9 percent CO_2. These short tests showed the emission levels that can be optimally obtained from a fabric filter; however, because of the short duration and the conditions and procedures used they are not considered to have demonstrated that those emissions can in fact be achieved in practice under normal operating conditions.

2. Unpublished results [20] from an EPA-sponsored test of a fabric filter at the Braintree, Massachusetts incinerator in 1979 gave emissions averaging 0.039 gr/dscf (89 mg/dscm) corrected to 12 percent CO_2 (0.010 to 0.096).

3. A one-bag filter test at the Pasadena, California incinerator in 1960 was reported [6] to have given 0.0009 gr/scf (2 mg/scm). Operational problems particularly with temperature excursions were reported.

4. Apitron [21] ran a small test of their electrostatically aided fabric filter on the Tonawanda, New York incinerator in 1978, producing emissions of about 0.0004 gr/dscf (0.83 mg/dscm) corrected to 12 percent CO_2. The results from this test were favorable, but the operability and economics of the system over a longer period of operation need to be demonstrated.

5. Teller Environmental Systems has run a 150 tons/day pilot (75 Mg/day) test of their chromatographic dry scrubbing system using an electrostatic precipitator at Isogo Yokahama, Japan. Particulate emissions of 0.026 gr/dscf (59 mg/dscm) at 12 percent CO_2 have been reported [22]. They have also operated a 300 tons/day (150 Mg/day) dry scrubbing pilot plant with a baghouse on the Framingham, Massachusetts incinerator for about a year. They have recently revealed data showing emissions of 0.0067 gr/dscf (15 mg/dscm) [23].

Only three commercial installations of fabric filters on municipal incinerators are known. A unit on the East Bridgewater incinerator operated intermittantly for several years, but is now shut down. Performance data on the unit are very sparse but an emission rate of 0.024 gr/dscf (55 mg/dscm) corrected to 12 percent CO_2 has been published [9]. Very little has been published about the units at Neuchatel, and Yverdon, Switzerland, except that the emissions at Neuchatel are approximately 0.05 gr/dscf (110 mg/dscm) corrected to 12 percent CO_2. RESCO has had a pilot unit operating at their Saugus incinerator for some time but have not yet released any data.

From these data, it appears that BACT is an ESP which should produce emissions of 0.025 gr/dscf (57 mg/dscm) corrected to 12 percent CO_2 or lower since several operating incinerators meet that level (Baltimore 4, Nashville 1, Saugus). Predicting LAER is more difficult in that only one municipal incinerator has ever reported a lower level (Nashville 2 at 0.018 gr/dscf (41 mg/dscm)). That emission rate was obtained during a test on a new clean precipitator and no further data are available to show whether that emission rate was maintained. Data from other sources indicate that efficiency is at a maximum for a new precipitator and deteriorates with time [10, 24]. A second similar precipitator and furnace at Nashville were found to be emitting 0.024 gr/dscf (55 mg/dscm) corrected to 12 percent CO_2 in a similar test. Many manufacturers of precipitators are willing to guarantee that their units will meet 0.018 gr/dscf (41 mg/dscm) initially but are normally not willing to extend the guarantee beyond the initial compliance test. At this time, there are few data to support LAER at a lower figure. The very low emissions achieved in the Nashville filter test were probably due to the choice of test conditions and procedures and are probably not achievable in commercial practice. Insufficient data are available from the Pasadena or Tonawanda tests to make any judgement as to the validity and applicability of that data. The 0.007 gr/dscf (15 mg/dscm) claimed for the Teller system at Framingham could be used to set a lower standard if sufficient data became available to verify the figures and establish that the test conditions were appropriate.

SULFUR DIOXIDE

EMISSIONS

Sulfur dioxide emissions from refuse incineration are a function of the amount of sulfur in the refuse. An average municipal refuse has been found to contain approximately 0.12 percent sulfur on an as received basis. Not all of the sulfur in the refuse appears in the flue gas as SO_2 when the refuse is incinerated. Depending upon type of incinerator and the form of the sulfur in the waste, between 40 and 80 percent of the sulfur is retained in the ash [25, 26, 27]. Battelle feels that a 50 percent retention factor is reasonable for a mass-burning incinerator. On these bases an emission rate of 2.4 lb/ton (1.2 kg/Mg) of refuse burned can be calculated. From the previously mentioned flue gas flow rate, a concentration of 80 ppm* can be derived. The sulfur dioxide concentrations reported in the literature are shown in Table 5.

TABLE 5 SULFUR DIOXIDE EMISSIONS

Incinerator	lb/Ton	kg/Mg	actual ppm	ppm corr. to 12% CO_2	Ref.
Alhambra	1.9	(0.95)	88	105	25
Various			22-195		6
Braintree			45-54	136	4
Babylon			36		12
Babylon			35.1	78	28
Nashville			38	45	29
Chicago NW			107	137	12
E Hamilton			185		12
Newport News			65.6	254	30
SW Brooklyn			17.0	43.4	30
Oceanside			30		30
Oberhausen				96	15
Dusseldorf				193	7
Babylon			67	103	31
Various	2.5	(1.2)			8
Various	2.0	(1.0)			1
Harrisburg			75		3
Saugus	2.0	(1.0)			17
Average	2.25	(1.12)	69.4	120.6	
Std. Dev.	.25	(0.12)	56.4	64.9	

CONTROLS

Since the sulfur dioxide typically emitted from the mass-burning of municipal waste is considerably lower then emitted from most coals, sulfur dioxide controls have not been required on municipal incinerators; however, some state and local agencies most notably in California, are now requiring acid gas controls on new municipal incinerators. Acid gas controls (HC1 & HF) have been required on municipal incinerators in West Germany and Japan for several years, but it is generally accepted that the refuse in these countries contains considerably more acid forming materials than the U.S. refuse.

Wet scrubbers typically using caustic for a scrubbing solution have been common in Germany, but most of the new installations both in Germany and Japan have been dry scrubbers using lime as an absorbant. Teller Environmental Systems and DB Gas Cleaning have supplied most of the dry scrubbers for municipal incinerators. Of the seventeen dry scrubber installations identified, the only one in the U.S. is the Teller Pilot plant at the Framingham incinerator. Only three of these systems have been in operation over two years. Since the facilities are so new, little information is available about their performance. Information supplied by the manufacturers indicate control efficiencies of 48 to 88 percent for SO_2 and 75 to 99 percent for HC1.

The ability of these scrubbers to reduce SO_2 and HC1 emissions from municipal incinerators appears to have been demonstrated in practice but no performance test data of adequate quality to meet EPA standards, has been found to verify the performance of the systems. While the scrubber systems may still be constructed at LAER without verifable performance data, operating costs (including amortization) of approximately $3.00/ton of refuse burned or over $1000**/ton of acid collected will probably preclude them from being established as BACT.

NITROGEN OXIDES

EMISSIONS

The emission of nitrogen oxides from combustion sources are due to either the conversion of nitrogen in the fuel to nitrogen oxides, or to the fixation of atmospheric nitrogen at high temperatures. Generally, the relatively low peak temperatures occurring in mass burning municipal incinerators limit the NO_x emissions to levels below those occurring in most other combustion sources. The emissions of NO_x reported in the literature are shown in Table 6.

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*ppm v/v are used throughout the paper.

**Derived from [22].

TABLE 6 NITROGEN OXIDE EMISSIONS

Incinerator	lb/Ton	kg/Mg	actual ppm	ppm corr. to 12% CO2	Ref.
Various	3.0	(1.5)			8
Various	1.6	(0.8)			1
Braintree			94		6
Nashville			146	160	29
Babylon			35.8	78	31
Babylon			28.9	64.6	28
Newport News			39	151	30
NW Brooklyn			61.3	156	30
Oceanside			104		30
Oberhausen				159	15
Various			6-177		6
Chicago NW			179		12
E Hamilton			112		12
Harrisburg	2.64	(1.33)			12
Harrisburg			123		3
Saugus	2.25	(1.12)			17
Average	2.38	(1.19)	88.7	129.4	
Std. Dev.	.57	(0.26)	57.1	41.6	

The nitrogen oxide emissions reported are quite variable. We feel that the Rinaldi [1] value of 1.6 lb/ton (0.8 kg/Mg) of refuse burned, which is equivalent to about 75 ppm in the flue gas, is a reasonable and conservative value for a modern waterwall incinerator.

CONTROLS

Since the NO_x levels are naturally comparatively low, the control of NO_x is not practiced on mass-burning municipal incinerators. Combustion modification techniques applicable to fossil fuel-fired-boilers either are generally not applicable to the mass-burning situation or tend to cause higher CO emissions and unacceptable boiler corrosion. One of the add-on control systems available for fossil fuel-fired-boilers has been tested in Japan [32]. The results of the test showed that the NO_x could be reduced by 60 percent by injecting NH_3 under precise control into the incinerator firebox. About 20 ppm of unreacted NH_3 remaining in the gas caused precipitates of ammonium salts to form in the economizer.

This test does not appear to establish that these reductions have been "achieved in practice" by a municipal incinerator as required in the regulations to establish LAER or BACT and thereafore should not be used to establish BACT or LAER.

CARBON MONOXIDE

EMISSIONS

Carbon monoxide is a product of incomplete combustion and for municipal incineration depends largely on the overfire air ratio, the design of the overfire air jets, and the combustion temperature. Values of CO reported in the literature are shown in Table 7. Considering these data, we have chosen a somewhat conservative 150 ppm as a reasonable estimate for a modern incinerator design using the combustion control measures now commonly used to control boiler tube wastage. This is equivalent to an emission rate of 1.9 lb/ton (0.95 kg/Mg) of refuse burned.

TABLE 7 CARBON MONOXIDE EMISSIONS

Incinerator	lb/Ton	kg/Mg	actual ppm	ppm corr. to 12% CO2	Ref.
Various	35	(18)			8
Braintree			473*	1390	6
Nashville			153	176	29
Newport News			5.2-195		30
Various			6.1-179		6
Saugus	0.17	(0.08)			17
Average			103.3	783	
Std. Dev.			67.9	-	

* Incineration problems reported

CONTROLS

The CO emissions from modern incinerators are usually limited to a few hundred ppm by combustion control measures designed to achieve good combustion and minimize boiler tube wastage. The maintenance of a minimum temperature and adequate turbulence (usually by means of overfire air jets) in the firebox – as required to control flame length, insure complete combustion, and reduce the corrosion of the boiler tubes – normally provides adequate control of CO and no additional controls are required.

HYDROCARBONS

EMISSIONS

Hydrocarbons appearing in the flue gas of an incinerator are products of incomplete combustion. They are mostly low-molecular-weight hydrocarbons, aldehydes, and organic acids with traces of high molecular-weight compounds also present. Values reported for hydrocarbon emissions from municipal incinerators are shown in Table 8. Older refractory wall incinerators frequently have higher HC and CO emissions than modern waterwall incinerators. Considering these data, we have chosen an emission rate of 0.12 lb/ton (0.06 kg/Mg) which

is equivalent to approximately 16 ppm as a reasonable value for total hydrocarbon emissions for this type of incinerator.

TABLE 8 HYDROCARBON EMISSIONS

Incinerator	THC* kg/Mg	THC* lb/ton	THC* ppm	Aldehydes ppm	Organic Acids ppm	Ref.
Various	(0.75)	1.5				8
Various	(0.06)	0.12				9
Braintree			11.3	1.3		4
Newport News			10	0.1	1	30
Oceanside			1.5	0.26	1	30
Babylon				2.6	44	31
Various			25.5-42.5	0.15-1.06		6
Unknown	(0.116)	0.231				33
Unknown	(0.002)	0.003				17
Babylon				2.3	50.5	28
Average	(0.232)	.464	18.2	1.11	24.1	
Std. Dev.	(0.35)	.70	14.4	.95	23.2	

* Total hydrocarbons

CONTROLS

To the authors' knowledge, no municipal incinerator uses any type of add-on control to reduce hydrocarbon emissions and there are no published correlations between design or operating parameters and hydrocarbon emissions; however, it is reasonable to expect that measures used to control CO will control hydrocarbons even more effectively.

HYDROCHLORIC ACID

EMISSIONS

Flue gases from municipal incinerators normally contain hydrochloric acid as a by-product of the combustion of PVC, other chlorinated plastics, and sodium chloride found in the waste. Hydrochloric acid emissions are not regulated by the U.S. EPA, but most states require the emissions to be reported and control regulations are under consideration in several states. It has been reported that only about half of the chloride in the waste is converted to hydrochloric acid [28] and some of the evolved HCl may be removed on the ash particles [34] as the flue gases pass through the boiler and electrostatic precipitator. Emissions of hydrochloric acid reported in the literature are found in Table 9. Considering these data, we feel that 200 ppm or 3.4 lb/ton (1.7 kg/Mg) is a reasonable estimate of the hydrochloric acid emissions.

TABLE 9 HYDROCHLORIC ACID EMISSIONS

Incinerator	lb/Ton	kg/Mg	ppm	Ref.
Various	1.8	(0.9)		8
Oberhausen*			900**	15
Oceanside			113	30
Babylon			237	31
Nashville			110	29
Unknown	4.2	(2.1)	213	35
Unknown	4.2	(2.1)	230	35
Unknown	4.0	(2.0)	261	35
Unknown	4.0	(2.0)	258	35
Various			63-1260**	6
Harrisburg			273	3
Braintree			79	4
Babylon			226	28
Average	3.55	(1.78)	200	
Std. Dev.	1.01	(0.50)	67	

*Corrected to 12% CO_2 **Data point eliminated as nonrepresentative

CONTROLS

Wet scrubbers were commonly used on municipal incinerators in the past for particulate control, and more recently for gas cooling ahead of ESPs, and the acid control they gave was incidental. These scrubbers were incapable of meeting current particulate emission standards and heat recovery boilers have largely replaced water quenching so scrubbers became uncommon on municipal incinerators. Acid gas control has been required in West Germany and Japan for several years and is now being required by several local and state agencies, most notably in California.

Wet scrubbers are being used for acid gas control on municipal incinerators in West Germany in conjunction with electrostatic precipitators, and are common on hazardous waste incinerators; however, corrosion and waste water disposal problems have restricted their use on municipal incinerators. Where acid gas control is required, dry scrubbers are now commonly used. Of the seventeen scrubbing systems we are aware of that were installed in Germany and Japan in 1980 and 1981, eleven were dry scrubbers.

FLUORIDES

EMISSIONS

Traces of hydrogen fluoride from the combustion of fluorinated plastics or similar materials appear in the flue gas from municipal incinerators. There are no federal regulations limiting the emissions of fluorides from municipal incinerators, however the PSD regulations require that the fluoride emissions be estimated and reported. The emissions of fluorides from municipal incinerators reported in the literature are shown in Table 10.

6.1×10^{-4} [illegible] × $\frac{.0064\ lb}{2.4 \times 10^{-4}\ gr}$ [illegible]

= 0.16 [illegible]

TABLE 10 FLUORIDE EMISSIONS

Incinerator	ppm	Ref.
Oberhausen	20*	15
Babylon	4.8	31
Braintree	2.0	4
Babylon	5	12
Zurich	12	7
Dusseldorf	10	7
Average	6.4	
Std. Dev.	3.91	

*Corrected to 12% CO_2

Based on these data 6.5 ppm or 0.06 lb/ton (0.03 kg/Mg) has been chosen as a conservative estimate of fluoride emissions.

CONTROLS

Fluoride emission control is normally not required on municipal incinerators except in conjunction with acid gas control. Some of the fluoride appears to be associated with the particulate matter and therefore will be removed by the particulate control device while some is apparently present as a gas and would be removed in the acid gas scrubber. Very little fluoride removal data are available but it appears that the fluoride may be removed a little more efficently than the hydrochloric acid.

TRACE METALS, LEAD, MERCURY, BERYLLIUM

EMISSIONS

Some of the lead in the municipal waste is emitted with the fly ash from a municipal incinerator. The amount of lead emitted will depend upon the efficiency of the particulate control system. Some reported values of lead emissions for incinerators using electrostatic precipitators for particulate control are shown in Table 11. We have chosen 34,200 µg/g (0.034 lb/lb) of particulates or 0.012 lb/ton (0.006 kg/Mg) of refuse burned as a reasonable estimate of the lead emissions.

TABLE 11 LEAD EMISSIONS

Incinerator	$\frac{\mu g\ Pb}{g\ of\ Particulates}$	gr/dscf	$\frac{mg}{dscm}$	Ref.
Braintree		0.0024	(5.4)	4
Washington, D.C.	78,000			36
Various	18,100-34,200			1
Hamilton	5,700			6
Germany	20,100			6
Average	31,200			
Std. Dev.	25,100			

Trace amounts of mercury have been found in the emissions for municipal incinerators. Values reported in the literature are shown in Table 12. Based on the listed data, an emission of 2.4×10^{-4} gr/dscf (0.55 mg/dscm) or 0.0064 lb/ton (0.0032 kg/Mg) of refuse burned was chosen as a conservative estimate of total mercury emissions.

TABLE 12 MERCURY EMISSIONS

Incinerator	$\frac{\mu g\ Hg}{g\ of\ Particulates}$	gr/dscf	$\frac{mg}{dscm}$	Ref.
Braintree		6.1×10^{-4} particulate	(.014)	4
		2.4×10^{-4} vapor	(.55)	
Hamilton	300			6
Germany	133			6
Gent, Belgium		6.4×10^{-5} vapor	(.014)	37
Average	216	1.6×10^{-4}	(.037)	

Few data giving emissions of beryllium from municipal incinerators were found. The only reference to beryllium emissions was for the Braintree incinerator [4] where less than 0.15 µg/g of emitted particulates was reported. Using this data, based on the particulate emissions previously cited, the emissions of beryllium are estimated to be less than 5.6×10^{-8} lb/ton (2.8×10^{-8} kg/Mg) of refuse burned.

Trace quantities of a large number of other metals have been found in the fly ash from municipal incinerators. Most of them are present in very small quantities and are of little environmental concern. Concentrations of the more toxic metals are presented in Table 13.

CONTROLS

The trace metals are minor and variable constituents of the waste. Most of the metals except for mercury appear to concentrate in the bottom ash or fly ash. Data presented by Law [38], factored for the difference in efficiency between a baffle chamber and and ESP (95 percent), indicate that most of the mercury is emitted, less than 3 percent of the volatile metals (such as lead, cadmium and zinc) are emitted and less than 1 percent of the nonvolatile metals (such as barium, chromium, and copper) are emitted.

The data indicate that an effective particulate control system is about equally effective in controlling the trace metals. It is sometimes stated that a fabric filter's high efficiency for fine particulates makes it more efficient than other devices in collecting trace metals, but there is inadequate data to substantiate such superiority.

TABLE 13 CONCENTRATIONS OF SELECTED TRACE METALS IN MUNICIPAL INCINERATOR FLY ASH

Metal	μg/g				lb/Ton*	Kg/Mg
	Ref. 4	Ref. 36	Ref. 1	Average		
Arsenic	57	310	50-100	130	4.4×10^{-5}	(2.2×10^{-5})
Barium	340	990	270-540	540	1.8×10^{-4}	(0.9×10^{-4})
Cadimum	480	1900	670-1150	1100	3.8×10^{-4}	(1.9×10^{-4})
Chromium	200	870	130-260	360	1.2×10^{-4}	(0.6×10^{-4})
Copper	1600	1500	620-800	1100	3.8×10^{-4}	(1.9×10^{-4})
Nickel		170		170	5.8×10^{-5}	(2.9×10^{-5})
Zinc	+1%	14%	1%	5.3%	1.8×10^{-2}	(0.9×10^{-2})

*Based on particulate emissions of 0.34 lb/Ton (0.17 Kg/Mg)

SULFURIC ACID MIST

EMISSIONS

Very little data is available on emissions of sulfuric acid mist from municipal incinerators. Data from Harrisburg [3] give 0.0014 or gr/scf (3.2 mg/scm) which is 1.6 percent of the SO_2 emission rate. On the basis of the 2.4 lb/ton (1.2 kg/Mg) rate previously established for SO_2 emissions, a sulfuric acid mist emissions rate of 0.04 lb/ton (0.02 kg/Mg) of refuse burned can be calculated.

CONTROLS

Sulfric acid mist will be a vapor at high temperatures but, especially in the presence of moisture, will condense as an aerosol at lower temperatures. Most common pollution control systems will have low capture efficiencies but dry acid gas scrubbers (especially those utilizing fabric filters) should provide good control.

DIOXINS AND FURANS

EMISSIONS

Traces of polychlorinated dibenzo-*p*-dioxins and dibenzofurans have been identified in the emissions from a number of municipal incinerators abroad and in the U.S. The source or mechanism of formation of these compounds has not yet been discovered. Several theories have been proposed to account for their presence: they may be present in the feed and pass through the incinerator undestroyed; they may be formed from precursers such as chlorinated phenols, chlorinated benzenes, or PCBs. present in the feed; or they may be formed by the reaction of traces of chlorine present in the feed with complex organics formed in the combustion process. Much of the published data on dioxin emissions are not quantitative and the quantitative data available, as shown in Table 14, are very scattered. Several reports reviewing the literature on dioxins have been published [45, 46], but most of the data cited in this paper were derived from original literature sources where available.

In general, the variability of the data makes averages derived from it statistically meaningless except possibly for tetrachlorodibenzo-*p*-dioxin (TCDD) which has received the most attention from the investigators. It can be observed that the emissions reported for the Dutch incinerators are considerably higher than the other reported emissions (TCDD = 54 vs. 5.8 ng/g for ESP fly ash and 100 versus 2 ng/g for stack particulates); that the more highly chlorinated isomers, particularly the hexa and hepta chloro isomers, are more plentiful than the tetrachloro isomers; that there is several times as much dioxin in the emitted particulate as in that collected in the ESP; and that there can be appreciable dioxins in the vapor phase. There is no indication of why the reported emissions from the Dutch and the U.S. incinerator are so high compared to the rest, however the preponderance of evidence seems to favor the lower numbers.

Considering the available data, we conclude that the best estimate of TCDD emissions possible is 1×10^{-9} to 5×10^{-7} lb/ton (0.5×10^{-9} to 2.5×10^{-7} kg/Mg) or refuse burned and that total dioxin emissions are possibly a factor of 10 higher. Data presented by Cavallaro [42] and others indicate that the concentration of the toxic isomer 2,3,7,8-TCDD will be about 5 percent of the total TCDD

TABLE 14 CONCENTRATIONS OF CHLORINATED DIOXINS AND FURANS EMITTED FROM MUNICIPAL INCINERATORS**

	(ng/m³)												
	Dioxins						Furans						
Incinerator	Cl_4	Cl_5	Cl_6	Cl_7	Cl_8	Total	Cl_4	Cl_5	Cl_6	Cl_7	Cl_8	Total	Ref.
Ontario	9	15	13	3	0.4	40.4							39
Netherlands	(130)*	(730)*	(1130)*	(1390)*	(780)*	(4160)	(280)*	(600)*	(1200)*	(1260)*	(300)*	(3640)*	40
Nashville	7.7		14	28	30	80							41
Milan 1	(2.5)*				(180)*						(31)*		42
	(11.7)**				(630)***						(550)***		42
	6.1				150						166		42
Milan 2	(0.2)*				(13)*						(0.9)*		42
					(100)***						(90)***		42
	1.1				35						22		42
Desio	(0.6)*				(35)*						(16)*		42
	(ND)***				(40)***						(51)***		42
	2.7				170						70		42
Busto	(0.6)*				(37)*						(70)*		42
	(0.8)				(11)***						(10)***		42
	0.1				0.6						0.12		42
Japan 1	4.8												43
Japan 2	8.5												43
Netherlands	2.4												43
Ontario 1	12												43
Ontario 2	9.3											100	43
Zurich	2*	8*	30*	60*	123*	220*	1*	4*	30*	40*	10*		44
Netherlands	100*	800*	1370*	1370*	310*	3950*	480*	960*	1130*	1600*	140*		44
•	54	182	326	288	106	956	111	196	361	177	18	863	44
U.S.	(40–120)***												45

*In fly ash from stack **In fly ash from ESP unless otherwise noted ***In vapor phase

TCDD Summary

ESP partic. ng/g	6±4	11	50	2×10^{-9}
stack partic. ng/g*	2	1	100	7×10^{-10}
stack partic. (ng/m3)*	10±1	4	130	1×10^{-7}
gaseous (ng/m3)***	4±6	3	(80 USA)	4×10^{-8}

TABLE 15 TCDD CONTENT OF MUNICIPAL INCINERATOR FLY ASH ng/g (ng/m³)

Incinerator	2,3,7,8-TCDD	Total TCDD	%	Ref.
Milan 1	0.29	6.1	4.8	42
Milan 2	0.065	1.1	5.9	42
Desio	0.14	2.7	5.2	42
Netherlands	(3.9)	(130)	5.2	41
Average	0.22	4.4	4.8	

concentration or about 5×10^{-10} lb/ton (2.5×10^{-10} kg/Mg) of refuse burned as shown in Table 15.

CONTROLS

There are at this time no proven means of reducing the emission of these materials although increases in particulate control efficiency should reduce dioxin emissions to the extent that the dioxins are associated with the particulates. Some tests on power plants and power boilers co-firing refuse and coal have not shown any dioxin and there is speculation that more rigorous combustion conditions will reduce emissions. As yet, however, we have found no data to establish the effects of combustion temperature, residence time, or any other variable on the dioxin emissions.

POLYNUCLEAR AROMATIC HYDROCARBONS

Polynuclear aromatic hydrocarbons are common products of incomplete combustion of carbonaceous fuels and have been found in the emissions from many sources, including municipal incinerators. The various investigators did not identify the presence of the same compounds but pyrene, fluoranthene and benzoanthracene were major constituents in many cases. The published data are

TABLE 16 POLYNUCLEAR AROMATIC HYDROCARBON EMISSIONS

Incinerator	μg/g	(μg/m³)	lb/Ton*	kg/Mg	Ref.
Braintree		(20)	$4x10^{-4}$	$(2x10^{-4})$	8
[illegible]	0.6		$0.3x10^{-4}$	$(0.2x10^{-4})$	43
[illegible]	4.2		$2x10^{-4}$	$(1x10^{-4})$	47
Basingstoke, England		(4.20)	$0.8x10^{-4}$	$(0.4x10^{-4})$	46
[illegible]			$40.3x10^{-4}$	$(20x10^{-4})$	1
Average			$10x10^{-4}$	$(5x10^{-4})$	

*Calculated

shown in Table 16. Considering the wide variation of the available data, we have selected an average value of 1 X 10^{-5} lb per ton (0.5 X 10^{-5} kg/Mg) of refuse burned or 30 μg/g of emitted particulates.

POLYCHLORINATED BIPHENYLS (PCBs)

PCBs have been found in trace amounts in several municipal incinerator emissions. These materials probably result from incomplete destruction of traces of PCBs found in the waste feed. Since the manufacture and distribution of PCBs is now prohibited, the amounts found in the refuse, and therefore the amount in the emissions, can be expected to decline in the future. The reported PCB emissions are shown in Table 17.

Considering these data, 5 X 10^{-6} gr/dscf (0.011 mg/dscm) or 1.3 X 10^{-4} lb/ton (0.65 X 10^{-4} kg/Mg) is a reasonably conservative value for PCB emissions from municipal incinerators.

TABLE 17 PCB EMISSIONS

Incinerator	lb/Ton	(Kg/Mg)	gr/dscf	(mg/dscm)	Ref.
Chicago NW	$1.2x10^{-4}$	$(0.6x10^{-4})$	$5.5x10^{-6}$	(0.013)	49
Dade Co			$4.8x10^{-6}$*	(0.011)	50
Braintree			$1.6x10^{-6}$**	(0.0037)	8

* As Aroclor ① 1254 ** As decachlorobiphenyl

ASBESTOS

No data were found on the emissions of asbestos from municipal incinerators. Some asbestos may occur in municipal waste and small quantities may be suspended in the flue gas, but the particulate control equipment is expected to remove most of it and the emissions are expected to be insignificant.

VINYL CHLORIDE, H_2S, TRS*

No reports of the detection of these materials in the emissions from a municipal incinerator were found. Since these materials would be readily oxidized under the conditions prevailing in the incinerator, we conclude that there will be essentially zero emissions of these materials and that BACT is the standard combustion controls normally used on these units.

CONCLUSIONS

Published data on the emissions from municipal incinerators have been used to derive emission factors for a modern mass burning, waterwall municipal waste incinerator equipped with an electrostatic precipitator. These emission factors are summarized in Table 18.

TABLE 18 SUMMARY OF EMISSION FACTORS

Pollutant	Concentrations ppm or (gr/dscf)	lb/Ton
Particulates	(0.02)*	0.34
Sulfur Dioxide	80	2.8
Nitrogen Oxides	75	1.6
Carbon Monoxide	150	1.9
Hydrocarbons	16	0.12
Hydrochloric Acid	200	3.4
Fluorides	6.5	0.06
Lead	$(6.8x10^{-4})$*	0.012
Mercury	$(2.4x10^{-4})$	0.0044
Beryllium	$(3.0x10^{-9})$*	$5.3x10^{-8}$
Sulfuric Acid Mist	(0.0023)*	0.04
Tetrachlorodibenzo-p-dioxins		$1x10^{-8}$
Polynuclear Aromatics		$1.0x10^{-5}$
Polychlorinated Biphenyls		$1.3x10^{-4}$

*Corrected to 12% CO_2

These factors have been used in several instances to provide the emissions estimates for proposed incinerators for use in permit applications and environmental impact reports.

State-of-the-art control systems have been identified for each emitted pollutant as an aid in identifying BACT and LAER. A summary of these systems is presented in Table 19. In general, we have concluded that while thermal nitrogen oxide reduction systems and fabric filters show promise as improved pollution control systems, there is yet insufficient data in the literature to prove that they will maintain the claimed efficiencies under normal incinerator operating conditions.

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*Total reduced sulfur.

TABLE 19 STATE-OF-THE-ART CONTROL SYSTEMS

Pollutant	BACT	LAER
Particulates	ESP	ESP
Sulfur Dioxide	None	Dry or Wet Scrubber
Nitrogen Oxides	None	None
Carbon Monoxide	CC*	CC
Hydrocarbons	CC	CC
Hydrochloric Acid	None	Dry or Wet Scrubber
Fluorides	None	Dry or Wet Scrubber
Lead	ESP**	ESP**
Mercury	None	None
Beryllium	ESP**	ESP**
Sulfuric Acid Mist	None	Dry Scrubber
Dioxins	None	None
Polynuclear Aromatics	None	None
Polychlorinated Biphenyls	None	None
Asbestos	None	None
Vinyl Chloride	None	None
H_2S	None	None
Reduced Sulfur	None	None

*Standard modern combustion controls

**Controlled concurrently with particulates

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REFERENCES

[1] Rinaldi, G. M., *et al.*, "An Evaluation of Emission Factors for Waste-to-Energy Systems," EPA Publication 600/7-80-135, July 1980.

[2] U.S. EPA, Federal Register, 45, Sept. 11, 1980, p. 59875.

[3] Schulz, E. J., "Final Report on Harrisburg Municipal Incinerator Evaluation," Battelle's Columbus Laboratories to Harrisburg Incinerator Authority, Dec. 17, 1973.

[4] Golembiewski, M., *et al.*, "Environmental Assessment of a Waste-to-Energy Program: Braintree Municipal Incinerator," MRI Project No. 4390-L(14), NTIS publication PB 80-219421, Apr. 1979.

[5] Stabenow, G., "Performance of the New Chicago Northwest Incinerator," *Proc. 1972 Nat'l. Incin. Conf.*, ASME, New York, p. 178-195.

[6] Devitt, T. W., *et al.*, "Air Pollution Emissions and Control Technology for Waste as Fuel Process," EPA Contract 68-03-2509.

[7] Beltz, P. R., Engdahl, R. B., and Dartoy, J., "European Refuse-Fired Energy Systems. Evaluation of Design Practices," Vol. 2, EPA Publication SW-176 C.2, PB-80-115 322, 1979, Contract 68-01-4376, X2.

[8] "Compilation of Air Pollution Emission Factors," 3rd Ed, Ap-42, U.S. EPA, RTP 1977.

[9] U.S. EPA, Federal Register, 44:229, Nov. 27, 1979, p. 67938

[10] Bump, R. L., "The Use of Electrostatic Precipitators on Municipal Incinerators in Recent Years," *Proc. 1976 Nat'l Waste Processing Conf.*, ASME, New York, p. 193-201.

[11] Lingle, S. A., "Baltimore Pyrolysis and Waste-Fired Steam Generator Emissions," *Waste Age*, July 1976, p. 6.

[12] Simons, G., "Air Pollution Aspects of Resource Recovery Facilities," State of Calif., Air Resources Board, March 17, 1980, p. 110.

[13] Ried, R. S. and Heber, D. H., "Flue Gas Emissions from a Shredded-Municipal-Refuse-Fired Steam Generator," *Proc. 1978 Nat'l Waste Processing Conf.*, ASME, New York , p. 167.

[14] Engineering-Test Services, "Report of Particulate Emission Performance Tests . . . Nashville, Tenessee," March and August 1977.

[15] Feindler, K. S. and Plur, R., "From Coal to Refuse Power: The Successful Retrofit at Oberhausen," *Proc. 1980 Nat'l Waste Processing Conf.*, ASME, New York, p. 523.

[16] Private Communication, Phila. Dept. of Health, Air Management Services.

[17] Private Communication, Whelabrator Frye, Inc.

[18] Private Communication, American Air Filters, Inc.

[19] McKenna, J. D., *et al.*, "Applying Fabric Filtration to Refuse-Fired Boilers: A Pilot Scale Investigation," EPA Publication 600/7-78-078, PB 282 032, May 1978.

[20] Hall, F. D., *et al.*, "Evaluation of Pilot Scale Air Pollution Control Devices on a Municipal Waterwall Incinerator," EPA contract 68-03-2509, June 1980.

[21] Apitron Precision Ind. Inc., "Apitron Test-Tonawanda Incinerator, Tonawanda, N.Y.," Manufacturers Literature, April 6, 1979.

[22] Teller, A. J., "Dry System Emission Control for Municipal Incinerators," *Proc. 1980 Nat'l. Waste Processing Conf.*, ASME, New York, p. 581.

[23] Teller Environmental Systems, Inc., "Teller Environmental Systems, Inc. and the Teller Dry Chromatographic Emission Control System," Manufacturers Literature, undated.

[24] Teller, A. J., "New Systems for Municipal Incinerator Emission Controls," *Proc. 1978 Nat'l. Waste Conf.*, ASME, New York, P. 179.

[25] Kaiser, E. R., "The Sulfur Balance of Incinerators," *J. Air Poll. Control Assn.*, 18:3, March 1968, p. 171.

[26] Niessen, W., Sarofim, A., "The Emission and Control of Air Pollutants from the Incineration of Municipal Solid Waste," Second International Clean Air Compress, paper EN5C, p. 595.

[27] Niessen, W. R., *Combustion and Incineration Processes*, Dekker, 1978.

[28] Kaiser, E. R. and Carotti, A. A., "Municipal Incineration of Refuse with Additions of Plastics," *Proc. 1972 Nat'l Incin. Conf.*, ASME, New York, pp. 230 244

[29] Bozeka, C. G., "Nashville Incinerator Performance Tests," *Proceedings 1976 Nat'l Waste Processing Conf.*, ASME, New York, pp. 215-229.

[30] Jannke, J. A., *et al.*, "A Research Study of Gaseous Emissions from a Municipal Incinerator," *J. Air Poll. Control Assn.*, 27:8, Aug. 1977, p. 747.

[31] Carotti, A. A. and Kaiser, E. R., "Concentrations of Twenty Gaseous Chemical Species in the Flue Gas of a Municipal Incinerator," *J. Air Poll. Control Assn.*, 22:4, Apr. 1972, p. 248.

[32] Kitami, S., *et al.*, "Studies on Non-Catalytic NOx Reduction Technology for Municipal Refuse Incinerator," *Mitsubishi Heavy Industries Technical Review*, 17:1, 1980, p. 19.

[33] Private Communication, UOP, Inc.

[34] Franconeri, P. and Kaplan L., "Determination and Evaluation of Stack Emissions from Municipal Incinerators," *J. Air Poll. Control Assn.*, 26:9, Sept. 1976, p. 887.

[35] Rollins, R. and Homolya, J. B., "Measurement of Gaseous Hydrogen Chloride Emissions from Municipal Refuse Energy Recovery Systems in the United States," *Env. Sci. and Tech.*, 13:11, Nov. 1979, p. 1380.

[36] Greenberg, R. R., *et al.*, "Composition and Size Distribution of Particles Released in Refuse Incinerators," *Env. Sci. and Tech.*, 12:5, May 1978, p. 566.

[37] Dumarey, R., *et al.*, "Determination of Mercury Emissions from a Municipal Incinerator," *Env. Sci. and Tech.*, 15:2, Feb. 1981, p. 206.

[38] Law, S. L. and Gordon, G. E., "Sources of Metals in Municipal Incinerator Emissions," *Env. Sci. and Tech.*, 13:4, 1979, p. 432.

[39] Eiceman, G. A., *et al.*, "Ultrasonic Extraction of Polychlorinated Debenzo-*p*-dioxins and Other Organic Compounds from Fly Ash from Municipal Incinerators," *Analytical Chemistry*, 52:9, Aug 1980, p. 1492.

[40] Hutzinger, O., *et al.*, "Polychlorinated Dibenzo-*p*-dioxins and Dibenzofurans: A Bioanalytical Approach," *Chemosphere* 10, 1981, p. 19.

[41] Bumb, R. R., *et al.*, "Trace Chemistries of Fire: A Source of Chlorinated Dioxins," *Science* 210, Oct. 1980, p. 385.

[42] Cavallaro, A., *et al.*, "Sampling, Occurrence and Evaluation of PCDDs and PCDFs from Incinerated Solid Urban Waste," *Chemosphere* 9, 1980, p. 611.

[43] Eiceman, G. A., *et al.*, "Analysis of Fly Ash from Municipal Incinerators for Trace Organic Compounds," *Analytical Chemistry*, 51:14, Dec. 1979, p. 2343.

[44] Lustenhouwer, J. W. A., *et al.*, "Chlorinated Dibenzo-*p*-dioxins and Related Compounds in Incinerator Effluents: A Review of Measurements and Mechanisms of Formation," *Chemosphere*, 9, 1980, p. 501.

[45] Little, A. D., Inc., "Study on State-of-the-Art of Dioxin Combustion Sources," ASME, New York, 1981.

[46] Esposito, M. P., *et al.*, "Dioxins," EPA Publication 600/2-80-197, Nov. 1980.

[47] Davies, I. W., *et al.*, "Municipal Incinerator as Source of Polynuclear Aromatic Hydrocarbons in Environment," *Env. Sci. and Tech.*, 10:5, May 1976, p. 451.

[48] Hocking, M. B., "A Chemical Input-Output Analysis of Municipal Solid Waste Incineration," *J. Env. Systems*, 5:3, 1975, p. 163.

[49] Petkus, E. J., *et al.*, "Polychlorinated Biphenyl Emissions from a Municipal Incinerator," *Air Poll. Control Assn.*, paper 77-25.2, 1977.

[50] Feldman, J. B., *et al.*, "Evaluation of Emissions of Polychlorinated Biphenyl Compounds from the Incineration of Municipal Refuse and Swage Sludge," Air Poll. Control Assn. paper 77-19.4, 1977.

E.I. Supplement

AN EVALUATION OF EMISSION FACTORS FOR WASTE-TO-ENERGY SYSTEMS

Executive Summary

by

G. M. Rinaldi, T. R. Blackwood,
D. L. Harris, and K. M. Tackett

Monsanto Research Corporation
Dayton, Ohio 45407

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Project Officer
H. M. Freeman

Fuels Technology Branch
Energy Systems Environmental Control Division

INDUSTRIAL ENVIRONMENTAL RESEARCH LABORATORY
OFFICE OF RESEARCH AND DEVELOPMENT
U.S. ENVIRONMENTAL PROTECTION AGENCY
CINCINNATI, OHIO 45268

FOREWORD

When energy and material resources are extracted, processed, converted, and used, the related pollutional impacts on our environment and even on our health often require that new and increasingly more efficient pollution control methods be used. The Industrial Environmental Research Laboratory - Cincinnati (IERL-Ci) assists in developing and demonstrating new and improved methodologies that will meet these needs both efficiently and economically.

This report contains a summary of emission factors for the combustion of refuse for the purpose of providing energy recovery or volume reduction. This study was conducted to provide an up-to-date compilation of these factors for use in planning and assessing the benefits and risks from this industry. Further information on this subject may be obtained from the Fuels Technology Branch, Energy Systems Environmental Control Division.

David G. Stephan
Director
Industrial Environmental Research Laboratory
Cincinnati

ABSTRACT

The Industrial Environmental Research Laboratory (IERL) of the U.S. Environmental Protection Agency (EPA) has the responsibility for insuring that pollution control technology for stationary sources is available to meet the requirements of the Clean Air Act, the Federal Water Pollution Control Act, and the Resource Conservation and Recovery Act. The Fuels Technology Branch (FTB) of the IERL-Cincinnati has been assigned the responsibility for characterizing emissions from waste-to-energy systems. This report, prepared by Monsanto Research Corporation, is intended to supplement the document entitled "Compilation of Air Pollution Emission Factors" as a source of information concerning emission rates from solid waste combustion, since the latter does not incorporate the most recent technical data. Results presented herein will provide information to the EPA regional and program offices that is useful for decision-making regarding environmental research programs and the technological feasibility of compliance with existing or forthcoming regulations.

This state-of-the-art report, documented in a detailed final report which contains information on the data sources used and calculation procedures, was submitted by Monsanto Research Corporation in partial fulfillment of Contract No. 68-03-2550 under the sponsorship of the U.S. Environmental Protection Agency. This project was performed during the period November 1978 to May 1979. Mr. Harry Freeman of the Fuels Technology Branch at IERL-Cincinnati served as Project Officer.

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SECTION 1

INTRODUCTION

Generalized estimates of the magnitude of air pollution problems due to industrial sources can be made using derived numerical values known as "emission factors." An emission factor relates the mass of material released to some measure of source capacity, for example, grams emitted per quantity of fuel burned for combustion units. Thus, emissions data obtained from source testing, material balances, or engineering estimates can be reduced to numbers with a common basis for purposes of comparison. Such data, gathered for existing sources, can then be used to predict emission rates for systems either under development or under construction, indicating what air pollution control technology may be necessary to comply with applicable federal and state regulations.

Air pollutants generated by solid waste combustion include particulate matter and, in lesser amounts, hydrocarbons, oxides of nitrogen and sulfur, hydrogen chloride, polynuclear aromatic compounds, and trace elements. A literature search was conducted to generate emission factors from information compiled by other investigators. Results are presented herein for emissions of each particular pollutant from predetermined combustion categories. Although no uniform system of classification exists, all units were separated into three groups defined as follows for the purposes of this study.

- Category I: Mass-fired incineration in which the sole purpose is the reduction of the volume of municipal solid waste.
- Category II: Mass-fired incineration for both solid waste volume reduction and heat energy recovery for the generation of steam and/or electricity.
- Category III: Energy recovery from the combustion of refuse that has been upgraded in heating value by means such as selective removal of noncombustible material or addition of fossil fuel, i.e., coal, gas, or oil.

In the sections that follow, available data on combustion of coal only, in boilers suitable for the co-firing of refuse and fossil fuel (Category III), are presented for comparative purposes.

Water Wall

Category II is based on Braintree, Mass and Chicago, Ill. Waste-Fired Generators.

SECTION 2

EMISSIONS OF CRITERIA POLLUTANTS

PARTICULATES

Particulate emissions from combustion sources consist of particles of mineral matter and sometimes contain unburned combustible material. For this reason, earlier investigators of the environmental impact of incineration had speculated that the amount of particulate emissions could be related to the composition of the feed material, that is, the combustible fraction and/or ash content of that fraction. Data on these two feed characteristics for all three categories defined in Section I, as well as coal, are summarized in Table 1. The reported ash contents for Categories I and II differ only because of the specific data sources used in compiling Table 1; in general, average ash contents for these categories would be expected to be the same. However, the ash content of coal is typically greater than that of the combustible fraction of refuse, hence the difference between Category III and Categories I and II.

TABLE 1. TYPICAL COMBUSTIBLE FRACTIONS AND ASH CONTENTS OF FEED MATERIAL
(Percent by weight)

Category	Combustible fraction of feed material	Ash content of combustible fraction
I	71.6 - 85.7	1.6 - 10.8
II	79.1 - 81.6	2.5 - 7.1
III	100	12.7 - 18.8
Coal	100	11.7 - 20.2

The composition of municipal solid waste varies depending upon geographical location and time of year. In general, the combustible fraction consists of food waste; garden waste; paper products; plastic, rubber, and leather; textiles; and wood. The noncombustible material includes metals; glass and ceramics; and ash, rocks, and dirt. All the material for Category III is considered to be combustible because preprocessing techniques such as shredding, air classifying, screening, and magnetic separation of ferrous metals are usually practiced prior to feeding.

Emission Factors

Tables 2 through 5 provide data on uncontrolled particulate emissions for the three categories and coal combustion in a Category III boiler. The emission factors are given in four types of units, as follows:

1) grams of particulate per kilogram of combustible material fed (g/kg);
2) pounds of particulate per ton of combustible material fed (lb/ton);
3) grams of particulate per kilogram of combustible material fed, all divided by the ash content of the combustible fraction (g/kg/%A); and
4) pounds of particulate per ton of combustible material fed, all divided by the ash content of the combustible fraction (lb/ton/%A).

TABLE 2. EMISSION FACTORS FOR UNCONTROLLED PARTICULATES FROM CATEGORY I

Units[a]	Average	Range
g/kg	9.5	6.5 - 13
lb/ton	19	13 - 27
g/kg/%A	4.7	1.2 - 7.0
lb/ton/%A	9.4	2.5 - 14

[a] Based on mass of combustible feed material.

TABLE 3. EMISSION FACTORS FOR UNCONTROLLED PARTICULATES FROM CATEGORY II

Units[a]	Average	Range
g/kg	14	6.9 - 23
lb/ton	29	14 - 45
g/kg/%A	4.0	1.4 - 6.4
lb/ton/%A	8.0	2.7 - 13

[a] Based on mass of combustible feed material.

TABLE 4. EMISSION FACTORS FOR UNCONTROLLED PARTICULATE FROM CATEGORY III

Units[a]	Average	Range
g/kg	67	43 - 85
lb/ton	134	85 - 171
g/kg/%A	4.5	2.3 - 5.9
lb/ton/%A	9.0	4.7 - 12

[a] Based on mass of combustible feed material.

TABLE 5. EMISSION FACTORS FOR UNCONTROLLED PARTICULATES FROM COAL COMBUSTION[a]

Units[b]	Average	Range
g/kg	64	40 - 90
lb/ton	128	80 - 179
g/kg/%A	4.2	3.3 - 6.0
lb/ton/%A	8.4	6.6 - 12

[a] Data are for coal combustion in a boiler suited to cofiring of refuse-derived and fossil fuels.

[b] Based on mass of combustible feed material.

One of the most significant findings of this study is that emission factors for uncontrolled particulates from Categories I, II, and III and from coal combustion are essentially the same when reported on a normalized basis, that is, mass emitted per mass of combustible material fed, divided by the ash content of the combustible fraction. Referring to Tables 2 through 5, the average particulate emission factors for Categories I, II, and III and coal combustion are 4.7, 4.0, 4.5, and 4.2 g/kg/%A, respectively. Another relevant conclusion regarding particulate emissions is that, for Category I, the grate type (i.e., reciprocating, rocking, traveling) did not have a significant influence on the amount of pollutant generated. In addition, uncontrolled particulate emissions from Category III exhibited no clear trend as a function of boiler load (60% - 100%) or percent of heat input (20% - 50%) in the form of refuse.

Table 6 presents emission factors for uncontrolled particulates from Categories I, II, and III and coal combustion which were calculated by dividing the mass of emissions by the mass of total feed material. This data is provided for information purposes since many of the emission factors directly reported in the literature are in these units, or there may be insufficient characterization of the source to calculate emission factors on the basis of Tables 2 through 5 of this report. The numbers in Table 6 for Category III and coal combustion are identical to those in Tables 4 and 5, respectively, because all the feed material is combustible. Table 6 differs from Tables 2 through 5 in that there is no apparent correlation among the emission factors for the various categories.

TABLE 6. EMISSION FACTORS FOR UNCONTROLLED PARTICULATES BASED ON TOTAL FEED MATERIAL

	Average		Range	
Category	g/kg	lb/ton	g/kg	lb/ton
I	13	25	8.6 - 18	17 - 36
~~II~~	10	20	5.6 - 15	~~11.2 - 30~~
III	67	134	43 - 85	85 - 171
Coal	64	128	40 - 90	80 - 179

Particulate Control Technology

Emission control equipment now used on incinerators has been designed primarily to remove particulates because that is the only criteria pollutant currently regulated by federal and state standards. Available techniques for particulate control include mechanical collection (using dry cyclones), wet scrubbing, and electrostatic precipitation. Collection efficiencies for each of these techniques as applied to municipal incineration are given in Table 7.

TABLE 7. COLLECTION EFFICIENCIES OF CONTROL SYSTEMS FOR PARTICULATE EMISSIONS FROM MUNICIPAL INCINERATION

Control system	Efficiency, percent
Mechanical collection (cyclones)	30 - 80
Wet scrubbing	
Wetted baffles	10 - 60
Settling chamber and water spray	30 - 60
Venturi scrubber	90 - 99+
Electrostatic precipitation	90 - 99+

The collection efficiency of dry cyclones is a function of stack gas flow rate and particle concentration, size, and density, a complete discussion of which can be found in Air Pollution, Third Edition, Volume IV: Engineering Control of Air Pollution. One generalization can be made: Only under ideal operating conditions can a dry cyclone attain a particulate control efficiency of 30 percent when applied to an incinerator.

The first two wet-scrubbing control systems listed in Table 7 are of the low-energy type, hence the low collection efficiencies. A wetted baffle system consists of one or more vertical plates which are flushed by water spray. A settling chamber is simply a large refractory-lined chamber wherein gravitational settling of coarse particulates occurs as the incinerator exhaust gas velocity is reduced. Spraying the walls and bottom of the chamber with water inhibits re-entrainment of collected particulates. The high pressure drops required for venturi scrubbing may make its operating costs noncompetitive relative to those for electrostatic precipitation.

Electrostatic precipitation is one of the most effective demonstrated techniques for control of particulate emissions from incineration. However, relative to other applications of electrostatic precipitation, removal efficiencies are limited because refuse incineration yields large volumes of gas containing particles of widely variable size and resistivity characteristics. In at least one case, mechanical difficulties with operation of an incinerator and its related support systems resulted in abnormally high particulate loadings which consequently caused an electrostatic precipitator to function at an efficiency well below its expected design value.

OTHER CRITERIA POLLUTANTS

Data are available in the open literature for the other criteria pollutants emitted from incineration: sulfur oxides, nitrogen oxides, and hydrocarbons. Emission factors for these compound classes, determined in the outlet gases from any particulate control device, are reported in Tables 8 through 11 using both metric and English units. These emission factors are based on the amount of pollutant released divided by the total feed material, not only the combustible fraction. Pertinent observations about each pollutant are discussed in the following sections. The incineration industry has not, to date, intentionally attempted to control any of the three gaseous pollutants.

TABLE 8. EMISSION FACTORS FOR OTHER CRITERIA POLLUTANTS FROM CATEGORY I

Pollutant	Emission factor			
	Average		Range	
	g/kg	lb/ton	g/kg	lb/ton
Sulfur oxides (as SO_2)	0.33	0.66	0.02 - 0.92	0.05 - 1.8
Nitrogen oxides (as NO_2)	0.36	0.72	0.28 - 0.44	0.56 - 0.88
Hydrocarbons (as CH_4)	0.17	0.34	0.004 - 0.80	0.008 - 1.6

TABLE 9. EMISSION FACTORS FOR OTHER CRITERIA POLLUTANTS FROM CATEGORY II

Pollutant	Emission factor			
	Average		Range	
	g/kg	lb/ton	g/kg	lb/ton
Sulfur oxides (as SO_2)	1.0	2.0	0.11 - 3.2	0.22 - 6.4
Nitrogen oxides (as NO_2)	0.8	1.6	0.46 - 1.2	0.92 - 2.3
Hydrocarbons (as CH_4)	0.06	0.12	0.013 - 0.12	0.027 - 0.24

TABLE 10. EMISSION FACTORS FOR OTHER CRITERIA POLLUTANTS FROM CATEGORY III

Pollutant	Emission factor			
	Average		Range	
	g/kg	lb/ton	g/kg	lb/ton
Sulfur oxides (as SO_2)	20	40	5.9 - 45	12 - 89
Nitrogen oxides (as NO_2)	1.5	2.9	0.8 - 2.6	1.7 - 5.1
Hydrocarbons (as CH_4)	0.003	0.005	0.001 - 0.005	0.002 - 0.01

TABLE 11. EMISSION FACTORS FOR OTHER CRITERIA POLLUTANTS FROM COAL COMBUSTION[a]

Pollutant	Emission factor			
	Average		Range	
	g/kg	lb/ton	g/kg	lb/ton
Sulfur oxides (as SO_2)	32	64	18 - 52	35 - 104
Nitrogen oxides (as NO_2)	2.1	4.2	1.7 - 2.9	3.4 - 5.9
Hydrocarbons (as CH_4)	0.003	0.005	0.002 - 0.005	0.003 - 0.01

[a] Data are for coal combustion in a unit suited to cofiring of refuse-derived and fossil fuels.

Sulfur Oxides

Sulfur oxide emissions from Categories I and II are substantially lower than those from Category III or coal combustion. As shown in Table 12, the sulfur content of solid waste (Category II) is much less than that of coal or even coal mixed with up to 50 percent refuse by heat content (Category III). The data of Table 12 on the sulfur content of the various feed materials does in fact correlate well with the emission factors shown in Tables 8 through 11.

TABLE 12. TYPICAL SULFUR CONTENTS OF COMBUSTIBLE FRACTION OF FEED MATERIAL

Category	Sulfur content, percent by weight (as S)
I	-[a]
II	0.18 - 0.31
III	1.41 - 4.84
Coal	3.06 - 6.66

[a] Data not available.

Nitrogen Oxides

Emissions of nitrogen oxides (NO$_x$) from combustion sources are due to nitrogen in the fuel or reactions between atmospheric nitrogen and oxygen at high temperatures. Generally, the nitrogen content of refuse is low. Therefore, differences in NO$_x$ emissions between Categories I and II as compared to Category III or coal combustion are the result of differences in furnace operating temperature. Nitrogen oxide emissions from Category I or II are lower because the large amount of excess air, as much as 200 percent, needed to introduce the solid waste into the furnace reduces the combustion zone temperature by dilution. Normalization of NO$_x$ emissions for percent excess air was beyond the scope of this project.

Hydrocarbons

When any combustible solid, such as coal or refuse, is heated in the absence of oxygen, combusitible gases are evolved. For example, unburned material on top of a grate-type fuel bed will be heated by combustion gases passing through from below, and volatile hydrocarbons will be released. In the case of incineration, a lesser mass of hydrocarbons is emitted than any other criteria pollutant, as can be seen by inspection of Tables 2 through 5 and 8 through 11. The larger amount of hydrocarbons emitted from mass-fired incineration relative to co-firing or coal combustion may be due to the generation of formaldehyde from the combustion of more cellulose fiber present as wood chips or paper products.

SECTION 3

EMISSIONS OF NONCRITERIA POLLUTANTS

HYDROGEN CHLORIDE

Flue gases from solid waste combustion contain hydrogen chloride, a by-product of the combustion of polyvinyl chloride and other chlorinated plastics found in the feed. Hydrogen chloride emission factors for the three categories discussed herein, as well as for coal combustion, are presented in Table 13. Such emissions from the combustion of mass-fired or co-fired refuse are greater than those for coal alone. However, no generalizations can be made about the magnitude of the deviation because several factors exist which may influence hydrogen chloride emissions. For instance, hydrogen chloride may be absorbed by the alkaline constituents of ash in the combustion chamber. Alternatively, particulate control techniques which involve water sprays may be as much as 80 to 95 percent effective on the soluble chloride gas. The fly ash removed by electrostatic precipitation may absorb some hydrogen chloride.

TABLE 13. HYDROGEN CHLORIDE EMISSION FACTORS

	Emission factor			
	Average		Range	
Category	g/kg	lb/ton	g/kg	lb/ton
I	0.7	1.4	0.14 - 1.6	0.28 - 3.2
II	—[a]	—[a]	—[a]	—[a]
III	1.6	3.2	0.9 - 2.3	1.7 - 4.7
Coal	0.2	0.4	0.09 - 0.5	0.2 - 1.0

[a] Data not available.

TRACE ELEMENTS

Certain chemical compounds of the following trace elements are potentially toxic to humans if deposited in the lungs: antimony, arsenic, cadmium, chromium, lead, nickel, selenium, and tin. It is possible for these toxic substances to be released from the incineration process. Tables 14 through 17 comprise a summary

TABLE 14. CONCENTRATIONS OF TRACE ELEMENTS IN PARTICULATE EMISSIONS FROM CATEGORY I

Element	Concentration,[a] µg/g or 10^{-6} lb/lb
Antimony	610 - 12,600
Arsenic	80 - 510
Barium	40 - 1,700
Bromine	320 - 6,700
Cadmium	520 - 2,300
Chlorine	99,000 - 330,000
Chromium	70 - 1,800
Cobalt	2 - 30
Copper	970 - 6,800
Iron	1,700 - 18,000
Lead	50,000 - 155,000
Manganese	170 - 5,700
Nickel	40 - 440
Selenium	10 - 120
Silver	40 - 2,000
Tin	8,500 - 15,100
Zinc	47,000 - 240,000

[a] Data are for trace element content of particulates downstream of any pollution control device; i.e., controlled emissions.

[illegible] TSP

TABLE 15. CONCENTRATIONS OF TRACE ELEMENTS IN PARTICULATE EMISSIONS FROM CATEGORY II

Fwe [illegible]

Element	Concentration, µg/g or 10^{-6} (lb/lb) Uncontrolled	Controlled
Antimony	260 - 620	460 - 1,000
Arsenic	50 - 70	50 - 100
Barium	270 - 540	270 - 540
Bromine	420 - 2,400	350 - 1,200
Cadmium	380 - 820	670 - 1,150
Chlorine	>10,000	>10,000
Chromium	50 - 560	130 - 260
Cobalt	10 - 100	5 - 50
Copper	420 - 590	620 - 800
Iron	970 - 1,090	2,000 - 2,130
Lead	11,600 - 17,500	18,100 - 34,200
Manganese	420 - 1,400	140 - 490
Nickel	-[a]	-[a]
Selenium	<30	<30
Silver	110 - 200	50 - 110
Tin	2,600 - 5,000	1,400 - 5,000
Zinc	>10,000	>10,000

[a] Data not available.

TABLE 16. CONCENTRATIONS OF TRACE ELEMENTS IN PARTICULATE EMISSIONS FROM CATEGORY III

Element	Concentration, μg/g or 10^{-6} lb/lb Uncontrolled	Concentration, μg/g or 10^{-6} lb/lb Controlled
Antimony	0.4 - 10	2 - 180
Arsenic	20 - 80	140 - 740
Barium	-[a]	-[a]
Bromine	-[a]	-[a]
Cadmium	0.3 - 1.4	0.2 - 10
Chlorine	-[a]	-[a]
Chromium	5 - 20	60 - 100
Cobalt	0.6 - 2.0	4 - 40
Copper	10 - 50	50 - 280
Iron	700 - 2,410	6,940 - 17,300
Lead	1,220 - 2,930	4,470 - 18,400
Manganese	10 - 20	110 - 240
Nickel	3 - 20	20 - 190
Selenium	10 - 40	20 - 430
Silver	-[a]	-[a]
Tin	50 - 150	260 - 870
Zinc	860 - 3,770	4,360 - 17,200

[a] Data not available.

TABLE 17. CONCENTRATIONS OF TRACE ELEMENTS IN PARTICULATE EMISSIONS FROM COAL COMBUSTION

Element	Concentration, μg/g or 10^{-6} lb/lb Uncontrolled	Concentration, μg/g or 10^{-6} lb/lb Controlled
Antimony	7 - 20	10 - 150
Arsenic	20 - 120	20 - 680
Barium	-[a]	-[a]
Bromine	-[a]	-[a]
Cadmium	0.6 - 1.0	2 - 8
Chlorine	-[a]	-[a]
Chromium	6 - 8	30 - 40
Cobalt	0.4 - 1.5	3 - 30
Copper	6 - 7	30 - 40
Iron	2,350 - 2,800	13,200 - 18,200
Lead	340 - 380	1,050 - 1,790
Manganese	20 - 40	100 - 140
Nickel	6 - 20	30 - 40
Selenium	10 - 50	30 - 40
Silver	-[a]	-[a]
Tin	20 - 30	30 - 270
Zinc	180 - 560	910 - 3,340

[a] Data not available.

of available information on the trace element content of particulates emitted from incineration, including data taken before and after pollution control devices for Categories II and III and for coal combustion.

Other investigators have determined that Category I incinerators operating in different geographic regions of the United States and serving different types of communities have similar trace element emissions. Also, no significant day-to-day or seasonal changes in particulate composition were observed at any one site. The major constituents of controlled particulate emissions from Category I incineration, in approximate decreasing order by concentration, are chlorine, zinc, lead, tin, and iron. The dominant presence of the first three of these elements is due to the abundance of the elements in the fuel as fired. This phenomenon is best shown for Category II, as can be seen from the relatively large concentrations of chlorine, lead, and zinc in Table 15.

Other significant observations can be drawn from the data for Category II. First, the maximum concentrations of all trace elements in the controlled particulate emissions from Category II are less than the corresponding values for Category I. Category II incinerators extract more heat energy from the exhaust stream than Category I incinerators. This added heat recovery may be sufficient to cool the stack gases to the point that volatile elements can condense and therefore be more efficiently removed by the particulate control devices.

The data for Category II also demonstrate the selective fractionation of volatile elements into fine particles, those most likely to escape any attempted control. Elements previously shown to occur primarily in the fine-particle regime, that is, less than two micrometers in diameter, are not collected by the control device; some of these elements are antimony, cadmium, and lead. Since the large particles are removed, the ratio of the weight of these elements to the total mass is increased. This increase in concentration has potentially negative implications for human health effects because fine particulates can more easily reach the lower respiratory tract.

Element fractionation discussed above for Category II is also evident in the data for Category III and for coal combustion. In the latter two cases, the effect can also be readily seen for three more volatile elements: arsenic, selenium, and zinc.

Another point of interest is a comparison of the trace element contents of uncontrolled particulate emissions for the three categories and for coal combustion. The composition of particulates from Category III, for which the fuel is a mixture of solid waste and coal, and from coal combustion are approximately the same, with the possible exceptions of lead and zinc, which appear to a greater extent for Category III. This difference must be qualified, because the gas-phase emissions of these two elements, both of which are volatile, are not available.

Likewise, the apparently greater emissions from Category II relative to Category III must also be evaluated more closely. For example, consider the case for lead. The concentrations in uncontrolled particulates for Categories II and III are 11,600 to 17,500 μg/g and 1,220 to 2,930 μg/g, respectively; these values differ by a factor of four to fourteen, depending upon which values are compared. From Tables 3 and 4, the uncontrolled particulate emission factors for Categories II and III are 6.9 to 23 g/kg and 43 to 85 g/kg, respectively; these values differ by a factor of two to twelve, but in the opposite direction from those described above for trace element concentration. Therefore, when compared on the basis of micrograms emitted per kilogram of material burned, trace elements emissions from the mass-fired incineration of solid waste with heat recovery are not significantly different than those from the combustion of refuse co-fired with coal.

POLYNUCLEAR AROMATIC HYDROCARBONS AND POLYCHLORINATED BIPHENYLS

Polynuclear aromatic hydrocarbons are formed by the incomplete combustion of solid waste or other fuel material. Gases leaving an incinerator may contain polynuclear hydrocarbons both in the vapor phase and adsorbed on particulates. Emission factors for these compounds in stack gases downstream of any particulate control device are given in Tables 18 and 19 on the basis of mass emitted per mass of total material fed.

For Category I, more polynuclear hydrocarbons are emitted from small-sized furnaces because of poor combustion conditions relative to those in larger units. However, regardless of incinerator size, differing emission levels may be found during startup, normal operation, and shutdown. Wet scrubbing devices for particulate control at Category I incinerators have proven highly effective in reducing polynuclear hydrocarbon emissions; in one case, benzo(a)pyrene emissions were reduced by more than 95 percent.

Data on polynuclear hydrocarbon emissions from Category II is extremely limited. At one site, six compounds were observed in the gas phase: acenaphthylene, anthracene, fluoranthene, fluorene, phenanthrene, and pyrene. Fly ash collected by electrostatic precipitation contained acenaphthylene, anthracene, phenanthrene, and pyrene; however, all levels measured in both sample sets were below the range of reliable quantitative analysis.

TABLE 18. EMISSION FACTORS FOR POLYNUCLEAR AROMATIC HYDROCARBONS FROM CATEGORY I

Compound(s)	Emission factor μg/kg	Emission factor 10⁻⁶ lb/ton
Benzo(a)anthracene and chrysene	3.1[a]	6.2[a]
Benzo(b)fluoranthene, benzo(j)fluoranthene, and benzo(k)fluoranthene	1.4[a]	2.8[a]
Benzo(ghi)perylene	1.4 - 1.8	2.8 - 3.6
Benzo(a)pyrene and benzo(e)pyrene	0.08 - 1.5	0.16 - 2.9
Coronene	0.17 - 1.4	0.34 - 2.8
Fluoranthene	2.5 - 7.3	5.0 - 15
Indeno(1,2,3-cd)pyrene	0.77[a]	1.5[a]
Perylene	0.77[a]	1.5[a]
Pyrene	4.6 - 6.8	9.2 - 14

[a] Only one value reported.

TABLE 19. EMISSION FACTORS FOR POLYNUCLEAR AROMATIC HYDROCARBONS FROM CATEGORY III

Compound(s)	Emission factor μg/kg	Emission factor 10⁻⁶ lb/ton
Benzo(a)pyrene, benzo(e)pyrene, and perylene	0.76	1.5 ✓
1,2-Benzofluorene and 2,3-benzofluorene	0.57	1.1
Fluoranthene	1.2	2.5 ✓
Fluorene	0.38	0.76 ✓
Pyrene	0.38	0.76 ✓

Data on polynuclear aromatic hydrocarbon emissions from Category III are shown in Table 19. In addition, benzo(a)pyrene, benzo(e)pyrene, and perylene have been detected in particulates, but the amounts were not reported. Data on polynuclear hydrocarbon emissions from the combustion of coal only in a Category III boiler were not available.

Polychlorinated biphenyls could not be detected in particulates from either Category II or III or in vapor samples from Category III.

SECTION 4

COMPARISON WITH AP-42 FACTORS

The U. S. Environmental Protection Agency's "Compilation of Air Pollutant Emission Factors," or Publication No. AP-42, has long been used as source material for data on emissions from fuel combustion, incineration, evaporation losses, and miscellaneous other sources. Tables 20 and 21 compare the emission factors, in metric and English units, respectively, for uncontrolled criteria pollutants from municipal, industrial, and commercial incinerators as reported in AP-42, and for Categories I, II, and III and coal combustion as determined in this study. The numerical values in Tables 20 and 21 were calculated using total feed material as the basis.

For particulates, sulfur oxides, and nitrogen oxides, values given in AP-42 and those reported herein for Categories I and II, the most directly comparable combustion processes, overlap. The emission factors for hydrocarbons given in AP-42 are significantly higher than those found during the current investigation. This may be so because the most recent data source cited in the AP-42 review of refuse incineration was published in June 1971, whereas this report is based on information released as recently as December 1978. During that time, changes may have occurred in refuse composition, incinerator operation, or capabilities of sampling and analysis techniques used to determine emissions, thus resulting in the difference mentioned above.

TABLE 20. COMPARISON OF EMISSION FACTORS FOR UNCONTROLLED CRITERIA POLLUTANTS FROM INCINERATION AS REPORTED IN AP-42 AND THIS STUDY (metric units)

Category	Emission factor, g/kg Particulates	Sulfur oxides	Nitrogen oxides	Hydrocarbons
Municipal, industrial, & commercial incineration (AP-42)	3.5 - 15	1.25	1 - 1.5	0.75 - 7.5
I	8.0 - 68	0.02 - 0.92	0.28 - 0.44	0.004 - 0.80
II	5.6 - 15	0.11 - 3.2	0.46 - 1.2	0.013 - 0.12
III	43 - 85	5.9 - 45	0.8 - 2.6	0.001 - 0.005
Coal Combustion	40 - 90	18 - 52	1.7 - 2.9	0.002 - 0.005

TABLE 21. COMPARISON OF EMISSION FACTORS FOR UNCONTROLLED CRITERIA POLLUTANTS FROM INCINERATION AS REPORTED IN AP-42 AND THIS STUDY (English units)

Category	Emission factor, lb/ton Particulates	Sulfur oxides	Nitrogen oxides	Hydrocarbons
p.2-1.2 Municipal, industrial, & commercial incineration (AP-42) (1973)	7 - 30	2.5	2 - 3	1.5 - 15
I	17 - 36	0.05 - 1.8	0.56 - 0.88	0.008 - 1.6
II	11 - 30	0.21 - 6.4	0.92 - 2.3	0.027 - 0.24
III	85 - 171	12 - 89	1.7 - 5.1	0.002 - 0.01
Coal combustion	80 - 179	35 - 104	3.4 - 5.9	0.003 - 0.01

BIBLIOGRAPHY

In the following sections, literature examined during this investigation of emissions from waste-to-energy systems is listed. Those sources which had particular relevance to the evaluation of Category I, Category II, and Category III and coal combustion are cited separately. All other reference material gathered during this effort is also listed.

CATEGORY I

Carotti, A. A., and E. R. Kaiser. Concentrations of Twenty Gaseous Chemical Species in the Flue Gas of a Municipal Incinerator. Journal of the Air Pollution Control Association, 22(4):248-253, 1972.

Hangebrauck, R. P., D. J. von Lehmden, and J. E. Meeker. Sources of Polynuclear Hydrocarbons in the Atmosphere. Public Health Service Publication No. 999-AP-33, U.S. Department of Health, Education, and Welfare, Cincinnati, Ohio, 1967. 44 pp.

Davies, I. W., R. M. Harrison, R. Perry, D. Ratnayaka, and R. A. Wellings. Municipal Incinerator as Source of Polynuclear Aromatic Hydrocarbons in Environment. Environmental Science and Technology, 10(5):451-453, 1976.

Jahnke, J. A., J. L. Cheney, R. Rollins, and C. R. Fortune. A Research Study of Gaseous Emissions from a Municipal Incinerator. Journal of the Air Pollution Control Association, 27(8):747-753, 1977.

Greenberg, R. R., D. W. Neuendorf, and K. J. Yost. Composition of Particles Emitted from the Nicosta Municipal Incinerator. Environmental Science and Technology, 12(12):1329-1332, 1978.

Greenberg, R. R., W. H. Zoller, and G. E. Gordon. Composition and Size Distributions of Particles Released in Refuse Incineration. Environmental Science and Technology, 12(5):566-573, 1978.

Achinger, W. C., and L. E. Daniels. An Evaluation of Seven Incinerators. Publication No. SW-51ts.1j, U.S. Environmental Protection Agency, 1970. 39 pp.

CATEGORY II

Golembiewski, M., K. Ananth, G. Trischan, and E. Baladi. Environmental Assessment of Waste-to-Energy Process: Braintree Municipal Incinerator, Braintree, Massachusetts (Revised Draft Final Report). Contract No. 68-02-2166, U.S. Environmental Protection Agency, Cincinnati, Ohio, 1978. 233 pp.

Reed, J. C., J. D. Cobb, and J. C. Ting. Environmental Assessment of Combustion Processes for Industrial-Municipal Symbiosis in Refuse Disposal. In: AIChE/EPA Third National Conference on Water Reuse, Cincinnati, Ohio, 1976. pp. 337-344.

Stabenow, G. Performance of the New Chicago Northwest Incinerator. In: Proceedings of 1972 National Incinerator Conference, American Society of Mechanical Engineers, New York, New York, 1972. pp. 178-194.

CATEGORY III AND COAL COMBUSTION

Hall, J. L., H. R. Shanks, A. W. Joensen, D. B. Van Meter, and G. A. Severns. Emission Characteristics of Burning Refuse-Derived Fuel with Coal in Stoker-Fired Boilers. (Paper presented at the 71st Annual Meeting of the Air Pollution Control Association, Houston, Texas, June 25-30, 1978.) 16 pp.

Buonicore, A. J., and J. P. Waltz. District Heating with Refuse-Derived Fuel at Wright-Patterson Air Force Base. (Paper presented at the AIChE's Third Energy and Environment Conference, Cincinnati, Ohio, September 29 - October 1, 1975.) 10 pp.

Hall, J. L., A. W. Joensen, D. Van Meter, R. Wehage, R. Reece, H. R. Shanks, D. E. Fiscus, and R. W. White. Evaluation of the Ames Solid Waste Recovery Ststem, Part III. Environmental Emissions of the Stoker-Fired Steam Generators. EPA Grant No. R803903-01-0 and ERDA Contract No. W-7405 ENG-82. U.S. Environmental Protection Agency, Cincinnati, Ohio, and Energy Research and Development Administration, Washington, D.C., 1977. 774 pp.

Gorman, P. G., M. P. Schrag, L. J. Shannon, and D. E. Fiscus. St. Louis Demonstration Final Report: Power Plant Equipment, Facilities, and Environmental Evaluations. EPA-600/2-77-155b, U.S. Environmental Protection Agency, Cincinnati, Ohio, 1977. 433 pp.

OTHER LITERATURE

Shen, T. T., M. Chen, and J. Lauber. Incineration of Toxic Chemical Wastes. Pollution Engineering, 10(10):45-50, 1978.

Anderson, D. Emission Factors for Trace Substances. EPA-450/2-73-001, U.S. Environmental Protection Agency, Research Triangle Park, North Carolina, 1973. 80 pp.

Snowden, W. D., and K. D. Brooks. Case Study of Particulate Emissions from Semi-Suspension Incineration of Municipal Refuse. EPA-910/9-76-033, U.S. Environmental Protection Agency, Seattle, Washington, 1976. 87 pp.

Carroll, J. M., J. L. Hall, A. W. Joensen, and D. B. Van Meter. Source Emission Factors for Refuse-Derived Fuels. In: Proceedings of Conference on Sensing Environmental Pollution, New Orleans, Louisiana, November 6-11, 1977. pp. 472-478.

Gordian Associates, Inc. Overcoming Institutional Barriers to Solid Waste Utilization as an Energy Source. HCP/L-50172-01, U.S. Department of Energy, Washington, D.C., 1977. pp. 154-200.

Compilation of Air Pollutant Emission Factors, Third Edition. AP-42, U.S. Environmental Protection Agency, Research Triangle Park, North Carolina, 1977. 511 pp.

Corey, R. C. Incination. In: Air Pollution, Third Edition, Volume IV. Engineering Control of Air Pollution, A. C. Stern, ed. Academic Press, New York, New York, 1977. pp. 532-593.

Shanks, H. R., J. L. Hall, and A. W. Joensen. Environmental Effects of Burning Solid Waste as Fuel. In: Proceedings, of Conference on Sensing of Environmental Pollutants, New Orleans, Louisiana, November 6-11, 1977. pp. 739-741.

Interim Guide of Good Practice for Incineration at Federal Facilities. Publication No. AP-46, National Air Pollution Control Administration, Raleigh, North Carolina, 1969. 103 pp.

Background Information for Proposed New Source Performance Standards: Steam Generators, Incinerators, Portland Cement Plants, Nitric Acid Plants, and Sulfuric Acid Plants. APTD-0711, U.S. Environmental Protection Agency, Research Triangle Park, North Carolina, 1971. 50 pp.

Brinkerhoff, R. J. Inventory of Intermediate-Size Incinerators in the United States - 1972. Pollution Engineering, 5(11):33-38, 1973.

Funkhouser, J. T., E. T. Peters, P. L. Levins, A. Doyle, P. Giever, and J. McCoy. Manual Methods for Sampling and Analysis of Particulate Emissions from Municipal Incinerators. EPA-650/2-73-023, U.S. Environmental Protection Agency, Washington, D.C., 1973. 293 pp.

Williamson, J. E., R. J. MacKnight, and R. L. Chass. Multiple-Chamber Incinerator Design Standards for Los Angeles County. Los Angeles County Air Pollution Control District, Los Angeles, California, 1960. 32 pp.

Lee, Y. Fluidized Bed Combustion of Coal and Waste Materials. Noyes Data Corporation, 1977. 267 pp.

Shannon, L. J., and M. P. Schrag. Environmental Impact of Waste to Energy Systems. (Paper presented at the AIChE's Fourth Energy and Environment Conference, Cincinnati, Ohio, October 3-7, 1976.) 7 pp.

Cohan, L. J., and J. H. Fernandes. Incineration. In: Solid Wastes: Origin, Collection, Processing, and Disposal. John Wiley and Sons, Inc., New York, New York, 1975. pp. 259-332.

Rodes, C. E., M. D. Jackson, and R. G. Lewis. Monitoring for Polychlorinated Biphenyl Emissions from an Electrolytic Capacitor Disposal Project. EPA-600/4-78-025, U.S. Environmental Protection Agency, Research Triangle Park, North Carolina, 1978. 23 pp.

Rigo, H. G., S. A. Hathaway, and F. C. Hildebrand. Preparation and Use of Refuse Derived Fuels in Industrial Scale Applications. (Paper presented at the First International Conference and Technical Exhibition on the Conversion of Refuse into Energy, Montreux, Switzerland, November 3-5, 1975.) pp. 22-27.

Fiscus, D. E., P. G. Gorman, and J. D. Kilgroe. Refuse Processing Plant Equipment, Facilities, and Environmental Considerations at St. Louis - Union Electric Refuse Fuel Project. In: Proceedings of the National Wastes Conference, American Society of Mechanical Engineers, Boston, Massachusetts, May 23-26, 1976. pp. 373-384.

Trethaway, W. Energy Recovery and Thermal Disposal of Wastes Utilizing Fluidized Bed Reactor Systems. In: Proceedings of the National Wastes Conference, American Society of Mechanical Engineers, Boston, Massachusetts, May 23-26, 1976. pp. 117-124.

Kreutzman, E. Waste Destroying by Fluidizing Techniques. In: Environmental Engineering, Reidel Publishing Company, Dordrecht, Holland, 1973. pp. 403-411.

Clausen, J. F., C. A. Zee, J. W. Adams, J. C. Harris, and P. L. Levins. Monitoring of Combustion Gases during Thermal Destruction of Hazardous Wastes. In: Proceedings of Conference on Sensing Environmental Pollution, New Orleans, Louisiana, November 6-11, 1977. pp. 482-486.

HAYDEN-WEGMAN/CAROLLO
engineers
NEW YORK, NY — WALNUT CREEK, CA

NORTH SANTA CLARA COUNTY
SOLID WASTE MANAGEMENT AUTHORITY

AUTHORITY CONTRACT NO. 82-09

PROFESSIONAL SERVICES AGREEMENT
RESOURCE RECOVERY FACILITY DESIGN

Work Order No. 82-09-05

Summary Report
Assessment of Non-Criteria Pollutant Emissions

Prepared by
HAYDEN-WEGMAN/CAROLLO
engineers
New York, NY Walnut Creek, CA

October 25, 1983

330 WEST 42nd STREET NEW YORK, NEW YORK 10036 TELEPHONE (212) 563-6900
450 NORTH WIGET LANE WALNUT CREEK, CALIFORNIA 94598 TELEPHONE (415) 932-1710

NORTH SANTA CLARA COUNTY
SOLID WASTE MANAGEMENT AUTHORITY

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REFERENCES (Sheet 1 of 3)

A. "Sources of Metals in Municipal Incinerator Emissions",
S.L. Law & G.E. Gordon,
Environmental Science & Technology, April 1979

B. Cal Recovery Systems, Inc.
Report No. 83-01, March 1983

C. "Composition and Size Distribution of Particles Released in Refuse Incineration", R.R. Greenberg, W.H. Zoller and G.E. Gordon
Environmental Science & Technology, May 1978

D. "Composition of Particles Emitted from the Nicosia Municipal Incinerator", R.R. Greenberg, G.E. Gordon, W.H. Zoller R.B. Jacko, D.W. Neuendorf and K.J. Yost Environmental Science & Technology, Nov. 1978

E. "Environmental Assessment of a Waste-to-Energy Process, Braintree Municipal Incinerator", M. Golembiewski, K. Ananth, G. Trischan and E. Baladi, Contract 68-02-2166 to Industrial Environmetal Research Laboratory, USEPA NTIS publication PB80-219421, April 1979

F. Buonicore, A.J., Air Pollution Control Chemical Engineering, June, 1980, pp. 81-101

REFERENCES (Sheet 2 of 3)

G. "Resource Recovery and the New RCRA Regs", C. Gunther, Waste Age, February, 1981

H. K.P. Lindstrom Oct. 28, 1983 Communication on Ash Disposal including:

- excerpts on ash residue management from California Waste Management Board (CWMB) 1982 Report on Waste-To-Energy (WTE) projects.
- CWMB Agenda Item, April 26, 1983 for approval of a joint CWMB/EPA contract with Oak Ridge National Laboratory (ORNL) to conduct a study to determine the leaching characteristics of ash in a landfill environment including Exhibit A Scope of Work.
- Notes on June 15, 1983 CWMB Landfill Alternatives Conference.

I. California Waste Extraction Test (WET) data, subject to revision, provided by Gerry White, Analyst of the Office of WTE, CWMB, October 6, 1983 Telephone Communication. (See Table 82-09-05.2.3)

J. "An Evaluation of Emission Factors For Waste-To-Energy Systems"- Executive Summary, G.M. Rinaldi, T.R. Blackwood, D.L. Harris & K.M. Tackett, May 29, 1979 USEPA Contract No. 68-03-2550, Task II

K. "Emissions & Emission Control in Modern Municipal Incinarator", W.L. O'Connell, G.C. Stotler & R. Clark of Battelle's Columbus, OH Laboratories: 1982 ASME National Waste Conference Proceedings

L. "Municipal Incinerator Emission Estimates Onondaga County Resource Recovery Project", Arthur D. Litte, March 1981

M. "Public Health Aspects of Non-Criteria Pollutants Emitted from the Proposed San Francisco Resource Recovery Facility", E.T. Wei of University of California @ Berkeley, March 1982

N. Record of Telephone Communication of December 1, 1982 with Daryl Mills, California Air Resource Board

O. "An Overview: Dioxin Emission from Combustion Sources", A. Licata, Gibbs & Hill, Inc., ASME Solid Waste Processing Div. Mtg. Sept. 28, 1983.

NORTH SANTA CLARA COUNTY
SOLID WASTE MANAGEMENT AUTHORITY

Summary Report
Assessment of Non-Criteria Pollutant Emissions

1. Introduction

This Summary Report, in fullfillment of the Authority's Work Order No. 82-09-05, Item 2 quantifies emissions of non-criteria pollutants and estimates constituents anticipated in both fly ash and bottom ash.

Non-criteria pollutants are chemicals for which emission standards have not been fully developed, but are of interest because the ingestion of relatively small quantities may prove toxic to man and animal.

The non-criteria pollutant categories surveyed in this report are as follows:

- Trace Metals
- Hydrogen Chloride & Fluoride
- Sulfuric Acid Mist
- Hydrogen Sulfide
- Asbestos
- Aldehydes
- Carboxylic Acids
- Vinyl Chloride Monomers
- Polynuclear Aromatic Hydrocarbons
- Polychlorinated Biphenyls
- Dioxins
- Furans
- Pesticides and Herbicides

Each of the categories are covered under identifying paragraph headings.

2. Trace Metals

a) Overview

Metallic substances are present in both the combustible and non-combustible fractions of municipal solid waste (MSW). When incinerated in mass or RDF combustion systems, the metals report to the fly ash and/or bottom ash, sometimes unpredictably.

b) Estimated Emissions Impacting Air & Water Quality

Based on the material balance methodology presented in reference "A", factoring the laboratory analyses data for North Santa Clara County municipal solid waste (MSW) provided in reference "B", predictions were made of non-criteria pollutant metal emissions from both MSW and RDF combustion. These predictions are displayed in Tables 82-09-05.2.1 and 82-09-05.2.2 respectively. Predictions are given for:

(1) Uncontrolled Flyash
(2) Bottom Ash
(3) Total Ash
(4) Atmospheric Fly Ash, assuming air pollution controls operate at 99.5% efficiency.

The metal emissions are given for eight (8) Group I elements classified to be non-criteria pollutants by United States Environmental Protection Agency (EPA) and California Department of Health Services (CDOHS) and also for ten (10) Group II elements that only CDOHS has classified to be non-criteria pollutants. Emissions are stated in the following units:

*	$\frac{\text{lb of metal emitted (dry)}}{\text{1000 tons MSW @ 25\% } H_2O}$
ppm	parts per million, concentration of metal in ash category (1), (2), (3) or (4) above, uncorrected for ash products of acid gas control systems.

Both sets of units will be useful in evaluating predicted performance of facilities against both air and water quality standards that may be applicable in obtaining permits and environmetal approvals.

The emission unit * is more applicable in determining compliance with air pollution standards whereas concentration (ppm) has greater bearing on water quality standards. Ground or surface water quality may be contaminated by leachate from disposed ash having high concentrations of toxic metals in the ash.

c) Air Quality Standards

Over the past few years there has been increasing concern about toxic elements in our air. Some chemical species of heavy metals (such as beryllium, cadmium, mercury and lead) are generally considered to be toxic to humans when deposited in the lungs. These substances are carried predominantly by particulates in the small micron size range (e.g. less than 2 microns). From a toxicological viewpoint, these particulates are of paramount concern because they can bypass the body's respiratory filters and penetrate deeply into the lungs where the human bloodstream can extract toxic species at a high rate (60 - 80%) from particulate deposited in the pulmonary region. Conversely, extraction efficiency from larger particulates, which deposit in nasopharyngeal and tracheobronchial regions and are eventually removed to the pharynx by cilial action and swallowed, is low (about 5 - 15%). Reference "F".

EPA and/or the Bay Area Air Quality Management District (BAAQMD) have so far set maximum allowable emissions for lead, mercury and beryllium in new source performance standards requirements for incineration of waste materials. These requirements are:

	EPA	BAAQMD
Lead	None	15 lb/day
Mercury	3200 gm/day	3200 gm/day
Beryllium	None	10 gm/day

At 1000 TPD MSW throughput, predicted emissions for the North Santa Clara County waste combustion facility designs are well within the requirements, as follows:

	MSW Combustion	RDF Combustion
Lead	1.5 lb/day	0.5 lb/day
Mercury	9.07 gm/day	7.26 gm/day
Beryllium	0.02 gm/day	0.02 gm/day

Federal ambient air quality standards for locating major facilities within nonattainment areas are furthermore required by the Emission Offset Interpretive Ruling (40 CFR 51 Appendix S) to meet the Lowest Achievable Emission Rate (LAER) for those pollutants for which the area is nonattainment and are emitted in significant quantities. Significant quantities are defined for lead, mercury and beryllium as follows:

Lead	0.6 tons/yr
Mercury	0.1 tons/yr
Beryllium	0.0004 tons/yr

At 1000 TPD MSW (365,000 tons MSW per year) throughput, predicted annual emissions for the North Santa Clara County waste combustion facility design are within the "significant quantities" limits, as follows:

	MSW Combustion	RDF Combustion
Lead	0.27 tons/yr	0.09 tons/yr
Mercury	0.0036 tons/yr	0.0029 tons/yr
Beryllium	0.000008 tons/yr	0.000008 tons/yr

Predicted emissions for lead, mercury and beryllium are based on the data displayed in Tables 82-09-05.2.1 and 82-09-05.2.2. Predicted emissions for the other non-criteria metal emissions may likewise be compared with future EPA/BAAQMD standards for these emissions, once they are formulated.

d) Water Quality Standards

i. Federal Requirements

Pursuant to federal passage of the Resource Conservation and Recovery Act of 1976 (RCRA), United States Environmental Protection Agency (EPA) promulgated hazardous waste regulations (Reference "G") in May 1980. The regulations require the operator of a waste-to-energy (WTE) facility to determine whether the ash products of combustion are hazardous. If they are, the facility operator must notify EPA that the facility is a generator of hazardous waste, and the waste must be manifested (tracked) and managed and ultimately disposed in an approved hazardous waste landfill.

A waste is considered hazardous if it is ignitable, corrossive, reactive or toxic, or if it is listed in the regulations (40 CFR 261.20). Since ash from a WTE facility is not listed as hazardous wastes, they are only subject to regulations if they have one of the four hazardous waste characteristics.

For the WTE facility ash, the most important characteristic is toxicity and is determined by a test, developed by EPA called the Extraction Procedure (EP). This test is designed to identify those toxics which might be leached from landfill and pollute ground or surface waters.

To determine toxicity in the EPA test, an ash sample is leached with an acetic acid solution of pH5 or below for 24 hours. If the leachate contains heavy metals or pesticides in concentrations greater than one hundred times those permitted by the National Interim Drinking Water Standards (40 CFR 261.24), then the ash is defined as hazardous and must be managed and disposed as a hazardous waste.

Preliminary EPA EP tests have indicated most ash from WTE facilities are not hazardous. They found bottom ash samples taken from the following WTE plants to be nonhazardous:

(1) small modular combustor unit incinerator, rated 75 TPD burning residential waste only,

(2) large mass burning incinerator with capacity of over 1000 TPD burning MSW only (no industrial waste) and

(3) RDF incinerator, 300 TPD, burning RDF derived from MSW, commercial waste and selected industrial waste.

However the fly ash of both the large mass burning and RDF plants contained greater concentrations of cadmium and lead in the EP leachate than allowed by regulations.

In some WTE plants, the fly ash is automatically conveyed and mixed with bottom ash. If the fly ash is combined with the bottom ash within the process unit so that the toxic contaminants are diluted and the resulting mixture is nonhazardous, the combined ash would not be subject to RCRA (Subtitle C) regulations for manifest handling and disposal in an approved hazardous waste landfill.

Under RCRA's hazardous waste provisions, EPA itself must establish and enforce minimum federal standards for hazardous waste management and disposal. A State may supplant EPA authority if it establishes and enforces a hazardous waste plan that is at least equivalent to the minimum federal standards.

ii. State Requirements

For the past three years, the California Waste Management Board (CWMB) has assumed the lead role in resolving the uncertainties associated with the classification, handling and disposing of ash generated from the combustion of MSW at proposed waste-to-energy (WTE) facilities. CWMB's goals are to generate data to formulate the least costly, yet environmentally sound, management practices of handling and disposing of ash so as not to adversely impact ground and surface waters. CWMB has worked with two State of California regulatory agencies to resolve the ash disposal issues:

(1) Department of Health Services (DOHS), which determines the hazardous/nonhazardous status of waste materials. In determining a hazardous/nonhazardous classification, the DOHS evaluates the concentrations in wastes of heavy metals and organic compounds known to have deleterious health effects.

(2) State Water Resources Control Board (SWRCB), which regulates the disposal of all wastes to land to protect ground and surface water. The SWRCB classifies a waste based upon potential to degrade water quality. The parameters for classification include not only the soluble forms of the metals and organics evaluated by DOHS but also include soluble minerals, pH, alkalinity and several other water quality parameters. See Exhibit A.

A review of the current status of ash disposal requirements (References "H" & "I") being formulated for State of California WTE projects, indicates there are still uncertainties but that some of the issues are nearing resolution.

CWMB has estimated that the burning of MSW in the State's planned WTE plants will produce almost two million tons of ash annually that must be landfilled. If the ash is classified hazardous, CWMB predicts that six SB-1855 projects (Humboldt, Central Contra Costa, San Francisco, Alameda, Los Angeles County and San Diego) would spend $68 million (in 1982 dollars to dispose of about 1800 tons per day of ash they will produce, amounting to more than $100 per ton of ash). If the ash were classified as being nonhazardous costs would be reduced to about $3.5 million a year (again in 1982 dollars, amounting to less than $6 per ton of ash).

Because of the inability of the regulatory agencies to formulate definitive standards for classifying the ash, and the economic incentives to classify the ash as nonhazardous, in 1982, the DOHS issued a policy letter allowing for case - by -

case declassifications of ash at proposed WTE facilities based upon controlling the waste coming into the facility. Subsequent to the DOHS decision, several proposed projects: e.g. Fresco County Fresno-Clovis, Tri-Cities (Fremont, Union City and Newark), San Joaquin County (a private biomass-fired cogeneration project), Eureka, San Diego County, San Francisco, Long Beach and Modesto have received ash declassifications from DOHS but have experienced uncertain disposal requirements from Regional Water Quality Control Boards (RWQCB's). This uncertainty is based upon a lack of available data on the leaching characteristics of the ash in a landfill environment.

CWMB has proposed additional research to obtain the needed data on leaching characteristics of ash in the expectation that the research will support their contention that the wastes (MSW and MSW ash) are similar enough in leaching nature to manage in the same manner as nonhazardous materials.

iii. California Waste Extraction Test (WET)

In the meanwhile, CWMB has provided California Waste Extraction Test (WET) data which may serve as interim guidance on toxic metals allowed in ash (Reference I). The WET data is displayed in Table 82-09-05.2.3 and is intended to be used in lieu of the EPA Extraction Procedure.

The predicted concentrations for non-criteria metals in ash, displayed in Tables 82-09-05.2.1 and 82-09-05.2.2 may be checked against the Total Threshold Limit Concentration (TTLC) given in Table 82-09-05.2.3. TTLC concentration limits are set for the Nitric Acid Digestion Process proposed by CWMB. If ash samples pass this test, the ash is classified nonhazardous for toxic metals and there would be no need for the secondary test to determine Soluble Threshold Limit Concentrations.

Assuming composite ash samples (e.g. combined fly ash and bottom ash) will be allowed, a check of predicted non-criteria metal concentration for total ash (Column 3 in Tables 82-09-05.2.1 and 82-09-05.2.2) against respective TTLC's in Table 82-09-05.2.3 will indicate which of the metals have the potential to cause the ash sample to be classified hazardous. These are tabulated as follows:

	Concentration (ppm)		
	TTLC	MSW Combustion	RDF Combustion
Lead	1000	900	1100
Mercury	20	9.7	23
Antimony	500	187	626
Copper	250	2533	4708

Total ash concentration for RDF combustion are generally higher than for MSW combustion because weight of total ash is less for RDF combustion without commensurate reduction in the respective metal.

e) Literature Revue

A literature revue of non-criteria metals emissions from existing waste combustion facilities was performed in order to obtain the baseline data required to predict emissions for the proposed North Santa Clara County (NSCC) combustion facilities and then to compare measured emissions of existing waste combustion facilities with the emissions predicted for NSCC. The emission data, culled from the literature, is displayed in Tables 82-09-05.2.4 through 82-09-05.2.8. A discussion of these reference source tables and their relation to the metal emission estimates of tables 82-09-05.2.1 and 82-09-05.2.2 follows.

i. Table 82-09-05.2.4
Comparison of Average Non-Criteria Pollutant Metal Emmissions From MSW Combustion

Fly ash emission data obtained on four MSW combustion plants are excerpted from the reference sources: "C" for MSW incinerators at Washington D.C. SWRC #1 and at Alexandria, VA; "D" for the MSW incinerator at Nicosia, East Chicago, IN; and "E" for the Braintree, MA MSW mass burn waterwall incinerator.

Reference "C" is the companion paper to reference "A" which set forth the material balance methodology used in part in developing non-criteria metal emission & concentrations predictions for the proposed North Santa Clara County combustion facilities.

Reviewing the data in Table 82-09-05.2.4 for each of the non-criteria metals at respective plants, there appears to be reasonably good agreement in the composition of the suspended particles (e.g. atmospheric fly ash emissions). Some of the differences are attributed to the pollution control divices provided and the collection efficiencies that can be expected at respective plants. The Nicosia incinerator has a spray chamber followed by a plate type scrubbing tower, resulting in a total suspended particulate (TSP) emission of 8 lb/ton MSW. The Alexandria incinerator has a water-spray baffle with somewhat better collection efficiency, resulting in a TSP of 5.6 lb/ton MSW. Both Braintree and Washington D.C. employ electrostatic precipitators (ESP's) resulting in improved collection efficiencies; e.g. TSP's of 2.7 and 0.9 lb/ton MSW for Braintree and Washington D.C. respectively.

The air pollution control train proposed for the North Santa Clara County project would be designed for a superior collection efficiency of 99.5% on even small size particulate (e.g. 2 microns and less) which characterizes many of the trace metals. Assuming uncontrolled MSW combustion particulate emissions approximate 40 lb/ton MSW, this would result in a TSP controlled emission of 0.2 lb/ton MSW.

The 0.2 lb/ton MSW emission level would be a 4.5-fold improvement over the Washington D.C. SWRC #1 plant as regards collection of total suspended particulates. The superior collection efficiency proposed for North Santa Clara County is to be achieved by use of fabric filter bag house air pollution controls in lieu of electrostatic precipitators used at the Washington DC plant. The fabric filter is particularly effective in collecting the small micron sized particles which characterize the metal emissions. See Figure 1, "Fractional Efficiency Curves for Conventional Air Pollution Control Devices".

ii. Table 82-09-05.2.5
Emission Factors For TSP & HCl
Based on Total Feed Material

This table is based on data taken from Reference "J" report prepared by Monsanto Research Corporation under Contract to the Industrial Environmental Research Laboratory (IERL) of the U.S. Environmental Protection Agency (EPA) intended to supplement and update EPA's "Compilation of Air Pollution Emission Factors" as a source of information concerning emission rates from solid waste combustion. The reference report is purported to be state-of-the-art which would provide information to EPA regional and program offices that is useful for decision-making regarding environmental programs and the technological feasibility of compliance with existing or forthcoming regulations.

The table provides uncontrolled emission factors for total suspended particulates (TSP) for mass and RDF combustion facilities which are at odds with data developed by the California Air Resources Board (CARB) in a report issued on March 17, 1980. Comparative data is as follows:

	Emission Factors (lb/ton MSW)	
	Category II MSW Combustion	Category III RDF Combustion
Reference "J"	20	134
CARB Report	43	38

It is our judgement that the emission factors given in the CARB report would be more representative of the combustion facility designs proposed for North Santa Clara County and therefore the CARB emission factors are used as the data base in estimating non-criteria metal emissions and concentrations.

The 20 lb/ton MSW uncontrolled emission factor suggested in Reference "J" for Category II MSW combustion is believed to be too low since it is an average of data obtained under non-representative test conditions rather than normal day-to-day operations. Facility operators will use lower than normal excess air quantities when testing for particulate emissions compliance since furnace operations at low excess air will result in lower particulate emissions. Low excess air will however increase CO and HC emissions, but since statutory source emission regulations only require compliance with particulate emissions, the emphasis in the testing procedure in the past has been to operate the furnace so that particulate emissions are minimal, without concern about CO and HC emissions.

The 134 lb/ton MSW uncontrolled emission factor suggested in Reference "J", displayed in Table 83-09-05.2.5, for Category III RDF combustion is believed to be on the high side for converting trace metal concentrations, expressed in ppm, to actual metal emissions. The CARB estimate of 38 lb/ton MSW would be more appropriate for our purposes. The Reference "J" 134 lb/ton MSW emission factor is an average of tests performed on RDF spreader stoker furnaces that may have been undersized in furnace volume for the service. Accordingly, the carryover of particulate would be excessive. Furthermore, it would be expected, that much of the carryover is large particulate that could be collected in cyclone collectors installed upstream of the fabric filter bag houses, or it would fall out in the boiler passages or quench reactor towers upstream of the fabric filter bag houses. In any event, it is safe to assume that the bag houses would only see a total suspended particulate emission in the range of 38 lb/ton MSW (the CARB projection) rather than the 134 lb/ton MSW value given in Reference "J".

In reference "J", the MSW combustion system with heat recovery is designated Category II and the RDF combustion system with heat recovery is designated Category III. Both Categories II and III are of interest in comparing emission data observed by others with our predictions for the North Santa Clara County (NSCC) waste to energy project. Reference "J" includes emission data on MSW combustion without heat recovery (designated Category I) and also on coal combustion. The Category I and coal data is included in Table 82-09-05.2.5 and also in Tables 82-09-05.2.6 and 82-09-05.2.7. Category I data is of special interest since our predictions for NSCC emissions were based in part on a material balance methodology presented in reference "A" where experience in Category I combustion facilities was used as a basis of the analyses. There is sufficient agreement between Category I and II combustion to warrant this approach.

We believe too that much of the Category II test data from reference "J" is artificially low for reasons given above (e.g. facility operators for self-serving purposes using lower than normal excess air quantities when testing for particulate emissions since it will result in lower quantities of particulates emitted). Category I furnace operations generally require higher levels of excess air than does Category II for cooling the Category I refractory-lined furnaces to prevent overheating. This additional air for cooling is not normally required in Category II waterwall furnace operations since here the furnace is cooled by direct radiation to the waterwalls. Thus the Category I test data reported may in fact be more representative for Category II normal operations than the Category II test data itself.

In subsequent discussion, we will provide a cross-check between predictions for NSCC emissions based in part on Category I combustion with emissions reported by others for Category II as well as Category III combustion.

Hydrogen chloride emission factors that are given in Table 82-09-05.2.5 are discussed below in paragraph 3 covering Hydrogen Chloride & Fluoride.

iii. Table 82-09-05.2.6 Concentration of Trace Elements in Uncontrolled Particulate Emissions

MSW Combustion (Category II) Systems

Comparison of trace metal uncontrolled concentrations for MSW combustion (Category II) systems displayed in Table 82-09-05.2.6, taken from reference "J" with the uncontrolled concentrations predicted for NSCC given in Table 82-09-05.2.1 indicates relatively good agreement, with several exceptions noted as follows:

- Antimony - Predictions for NSCC at 1200 ppm are about twice that given for the highest of the range (260-620) given in Table 82-09-05-2.6 and is attributable to the higher than usual concentrations found by Cal Recovery Systems in NSCC MSW combustibles. See Table 82-09-05.2.9.

- Barium - Predictions for NSCC at 1040 ppm are again about twice the highest of the range (270-540) given in Table 82-09-05.2.6. Here however, the disparity cannot be explained by Cal Recovery Systems data, since they found average concentrations for barium in NSCC MSW combustibles to be lower than reported by others. See Table 82-09-05.2.9. This supports the hypothesis that barium in NSCC MSW noncombustibles may contribute to the higher barium concentrations that are predicted.

- Cadmium - Predictions for NSCC at 88 ppm are about 25% of the lowest of the range (380-820) given in Table 82-09-05.2.6 and may be explained by Cal Recovery Systems data, since they report very low levels of cadmium in NSCC MSW combustibles.

- Cobolt - NSCC predictions for cobolt at 160 ppm are higher than the range (10-100) given in Table 82-09-05.2.6. The Cal Recovery Systems data on cobolt in MSW combustibles indicates the cobolt level to be lower than reported by others. The higher cobolt concentrations that are predicted are surmised to be due to the cobolt in NSCC MSW noncombustibles.

- Lead - NSCC predictions for lead at 7360 ppm are somewhat lower than the range (11,600-17,500) given in Table 82-09-05.2.6. This is attributable to the lower than usual concentrations found by Cal Recovery Systems in NSCC MSW Combustibles, shown in Table 82-09-05.2.9.

RDF Combustion (Category III) Systems

Comparison of trace metal uncontrolled concentrations for RDF combustion (Category III) systems displayed in Table 82-09-05.2.6, taken from reference "J", with the uncontrolled concentration predictions for NSCC given in Table 82-09-05.2 indicates relatively good agreement for arsenic, lead and selenium but very poor agreement for antimony, cadmium, chromium, cobolt, copper, manganese, nickel and zinc. The disagreement is so great in concentrations given for antimony, cadmium, chromium, cobolt, copper, manganese & nickel, that the Category III data given in Table 82-09-05.2.6 for these metals is suspect of being in gross error.

Prediction of zinc concentration at 5,179 ppm in uncontrolled emissions in Table 82-09-05.2.2 is greater than the range (860-3,770) of Category III uncontrolled concentrations given in Table 82-09-05.2.6 for zinc. Yet in Table 82-09-05.2.9, Cal Recovery Systems shows zinc concentrations in NSCC combustibles fraction at about one-half that of the concentrations reported by others. The greater zinc concentration is attributed to the zinc in the noncombustibles fraction that is carried over into the RDF when processing MSW to RDF.

iv. Table 82-09-05.2.7
Concentration of Trace Elements in
Controlled Particulate Emissions

MSW Combustion (Category II) Systems

Comparison of trace metal controlled concentrations for MSW combustion (Category II) systems displayed in Table 82-09-05.2.7, taken from reference "J", with the controlled concentrations predicted for NSCC given in Table 82-09-05.2.1 follows the pattern for the uncontrolled concentration comparison of specific metals discussed above in paragraph iii, with the exception of copper.

- Copper - Whereas copper uncontrolled concentrations predicted for NSCC showed good agreement with the range of data presented in Table 82-09-05.2.6 for uncontrolled concentrations of copper, the controlled concentrations of copper at 440 ppm predicted for NSCC fall below the range of values (620-800) for controlled copper concentrations given in Table 82-09-05.2.7. An explanation for the observation may be the poor collection efficiency for copper particulates relative to the total suspended particulates in the air pollution control systems used at the plants which provided data sources for reference "J". In predicting NSCC controlled copper concentrations, displayed in Table 82-09-05.2.1, we expect a uniformly superior collection efficiency of 99.5% for all particulates including the copper.

RDF Combustion (Category III) Systems

Comparison of trace metal controlled concentrations for RDF combustion (Category III) systems displayed in Table 82-09-05.2.7, taken from reference "J", with the controlled concentrations predicted for NSCC given in Table 82-09-05-2.2 is compoundly difficult because of questionable accuracy of some of the data reported from reference "J". In general however, the agreement between the NSCC predictions are better for controlled concentrations than they are for uncontrolled concentrations. Further insights to the controlled concentrations differences will brought out in discussion of controlled emissions of trace elements presented in the following paragraphs:

v. Table 82-09-05.2.8
Controlled Emissions of Trace Elements

The controlled emission data (expressed in the unit lb/1000 ton), displayed in Table 82-09-05.2.8, is developed from the data given in Tables 82-09-05.2.5 and 82-09-05.2.7. To obtain the controlled emission for a trace metal displayed in Table 82-09-05.2.8, the controlled emission factor for total suspended particulates (TSP) given in Table 82-09-05.2.5 is multiplied by respective trace metal controlled concentration, given in Table 82-09-05.2.7. An example for antimony in the MSW combustion (Category II) system is a follows:

$$0.100\ \frac{\text{lb}}{\text{Ton}}\ \text{(Controlled Emission Factor for TSP)}$$

$$\times\ 460\ \text{ppm (Controlled Concentration for Antimony)}$$

$$= 0.100\ \frac{\text{lb}}{\text{ton}} \times \frac{460}{1{,}000{,}000} = \frac{0.046\ \text{lb}}{1000\ \text{tons}}$$

The controlled trace metal emission data of Table 82-09-05.2.8 (derived from reference "J" as indicated above) is compared to emissions predicted for NSCC. The NSCC emission data is given in column (4) of Table 82-09-05.2.1 for MSW combustion (Category II) systems and column (4) of Table 82-09-05.2.2 for RDF combustion (Category III) systems.

The following is a discussion of both sets of data for the trace metal emissions being compared:

- Antimony - emissions predicted for NSCC for both MSW (Category II) and RDF (Category III) combustion systems at about 0.24 lb/1000 ton MSW are about twice the maximum emissions shown in Table 82-09-05.2.8. The NSCC predictions for antimony are believed to be both conservative and realistic in view of Cal Recovery Systems' findings that antimony concentration in NSCC MSW combustibles are about twice that reported by others.

- Arsenic - Emissions predicted for NSCC for MSW combustion (Category II) systems at 0.01 lb/1000 ton MSW is on the high side of that shown in Table 82-09-05.2.8. Our prediction is therefore believed to be both conservative and realistic. We would expect RDF combustion (Category III) emissions would be about the same as for the MSW combustion (Category II) systems, as predicted in Table 82-09-05.2.2. The range of emissions (0.094-0.496) shown for Category III arsenic emissions in Table 82-09-05.2.8 derived from reference "J" is unbelievably high and will be disregarded.

- Barium - The 0.21 lb/1000 ton emission predicted for NSCC for MSW combustion (Category II) systems given in Table 82-09-05.2.1 is somewhat higher than shown in Table 82-09-05.2.8 (e.g. 0.21 vis-a-vis range of 0.027-0.054). Since Table 82-09-05.2.9 indicates barium concentrations in NSCC MSW combustibles to be 110 ppm compared to 170 reported by others, the higher 0.21 lb/1000 lb emission predicted for barium is presumed to be due to the barium MSW noncombustibles. See discussion in paragraph iii and iv above for uncontrolled and controlled concentrations of barium.

  Reference "J" provides no data on RDF combustion (Category III) systems to check against our 0.18 lb/1000 ton prediction for barium controlled emissions given in Table 82-09-05.2.2, Column (4).

- Cadmium - The 0.02 lb/1000 ton controlled emission predicted for NSCC for NSCC for MSW combustion (Category II) systems given in Table 82-09-05.2.1 is considerably below the range 0.067-0.115 shown in Table 82-09-05.2.8. This can be expected since Cal Recovery Systems found cadmium concentration in NSCC MSW combustibles to be less than one-third that reported by others.

  We believe that effective removal of noncombustible from the MSW, as is proposed in the RDF Manufacturing facility, will further reduce cadmium emissions to a level of 0.013 lb/1000 ton for the RDF combustion (Category III) system. See Table 82-09-05.2.2. This is somewhat higher than the range (0.0001-0.0067) shown in Table 82-09-05.2.8, but our analysis of the data does not justify a lower prediction than the 0.013 lb/1000 ton controlled emission rate given for cadmium in an RDF combustion (Category III) system.

- Chromium - The 0.08 lb/1000 ton controlled emission predicted for NSCC for MSW combustion (Category II) systems given in Table 82-09-05.2.1 is above the range (0.013-0.026) shown in Table 82-09-05.2.8. Although Cal Recovery Systems found chromium concentration in NSCC MSW combustibles to be about one-third that reported by others (see Table 82-09-05.2.0), we would expect noncombustibles in the MSW to also contribute to chromium emissions. The prediction for chromium emission at 0.08 lb/1000 ton is not considered excessive, but rather reasonably conservative, especially in view of the 0.040-0.067 range of controlled emissions for chromium shown in Table 82-09-05.2.8 for chromium in RDF combustion (Category III) system. Since we estimate that the noncombustible fraction of MSW can contribute as much chromium emissions as the MSW combustible fraction, our prediction for chromium controlled emissions in a RDF combustion (Category III) system is 0.04 lb/1000 ton.

- Cobolt - Assuming the cobolt in MSW noncombustibles contributes about twice the emissions of MSW combustibles, we predict controlled emissions for cobolt in a MSW combustion (Category II) system to be 0.03 lb/1000 tons. This level is above the 0.0005-0.005 range shown in Table 82-09-05.2.8. Although our prediction appears high relative to the reported range for Category II cobolt emissions, confidence in the 0.03 lb/1000 tons prediction is reinforced by the range of controlled emissions given for cobolt (0.0027-0.027) in an RDF combustion (Category III) system. Based on our assumptions, we predict controlled emissions for cobolt in a RDF combustion (Category III) system to be 0.016 lb/1000 tons. This prediction for the RDF combustion system follows from the 0.03 lb/1000 tons prediction for controlled emission of cobolt in a MSW combustion system. It is premised on most of the cobolt in the MSW noncombustibles being removed in the RDF manufacturing facility and not subjected to combustion. The 0.016 lb/1000 ton prediction falls in the 0.0027-0.027 range, given in Table 82-09-05.2.8 for the RDF combustion (Category III) system.

- Copper - The 0.09 lb/1000 ton copper controlled emission predicted for NSCC for MSW combustion (Category II) systems given in Table 82-09-05.2.1 is only slightly above the range (0.062-0.080) shown in Table 82-09-05.2.8. This may be attributable to the higher than usual concentration of copper in the NSCC MSW combustibles reported by Cal Recovery Systems. See Table 82-09-05.2.9.

  The 0.046 lb/1000 ton for controlled emission predicted for RDF combustion (Category III) systems given in Table

82-09-05.2.2 is within the range (0.034 - 0.188) shown in Table 82-09-05.2.8, however at the low end of the range.

Predictions on copper controlled emissions for MSW and for RDF combustion systems corroborate each other and are deemed reasonable.

- Lead - Cal Recovery System reports lead concentrations in NSCC MSW combustibles to be considerably lower than reported by others (e.g. 50 vis-a-vis 330 ppm), as shown in Table 82-09-05.2.9. This accounts for our 1.50 lb/1000 ton prediction for lead controlled emissions being below the range (1.810 - 3.420) given for Category II systems in Table 82-09-05.2.8. Our 0.50 lb/1000 ton prediction for lead controlled emission in RDF combustion (Category III) systems is considerably below the range (2.995 - 12.323) given for Category III in Table 82-09-05.2.8, but nevertheless would be expected because about two-thirds of the lead in MSW is removed with the noncombustibles in the RDF manufacturing facility and is not subject to the combustion process.

- Manganese - There is a high concentration of manganese in the combustible fraction of NSCC MSW, as reported by Cal Recovery Systems. At the same time, large quantities of manganese can be expected in the MSW noncombustibles. Although, most of the manganese would report to the bottom ash, sufficient manganese would be emitted to approach the controlled emission level prediction (0.33 lb/1000 tons) for MSW combustion (Category II) systems, even with air pollution controls operating at an estimated 99.5% collection efficiency.

  Manganese controlled emission for RDF combustion (Category III) systems is predicted to be 0.17 lb/1000 tons. This is only slightly above the range (0.074 - 0.161) given in Table 82-09-05.2.8 for the Category III systems and reinforces confidence in the 0.33 lb/1000 tons manganese controlled emission level predicted for MSW combustion (Category II) systems, despite the latter's disagreement with the range of values (0.014 - 0.049) given in Table 82-09-05.2.8.

- Nickel - Table 82-09-05.2.8 has no data relative to nickel controlled emissions for MSW combustion (Category II) systems and therefore we must forego a check on our 0.09 lb/1000 ton prediction given in Table 82-09-05.2.1.

  Table 82-09-05.2.8 does however provide a range (0.013 - 0.127) of controlled emissions for nickel in a RDF combustion (Category III) system which checks well with our 0.04 lb/1000 tons prediction of controlled emission for nickel in a RDF Combustion (Category III) System. It further reinforces confidence in our 0.09 lb/1000 ton prediction, given in Table 82-09-05.2.1 for cobolt controlled emissions in MSW combustion (Category II) systems, since the 0.09 lb/1000 ton prediction was our base for predicting the 0.04 lb/1000 tons value for controlled emission of nickel in RDF combustion systems.

- Selenium - Selenium controlled emissions for both MSW and RDF combustion (Category II and III) systems at 0.002 lb/1000 tons show good agreement with the range of data reported by others, as displayed in Table 82-09-05.2.8.

- Silver - Our controlled emission prediction for silver in a MSW combustion (Category II) system is 0.02 lb/1000 tons compared to the range (0.005 - 0.011) of values found by others displayed in Table 82-09-05.2.8. Although Cal Recovery Systems has not found excessive concentrations of silver in MSW combustibles, the amount of silver from the MSW noncombustibles could account for the 0.02 lb/1000 tons prediction.

  Table 82-09-05.2.8 provides no data for controlled emissions of silver in RDF combustion (Category III) systems to compare with our prediction of 0.015 lb/1000 tons for the controlled emission of silver in RDF combustion (Category III) systems. The 0.015 lb/1000 tons prediction follows from our earlier 0.02 lb/1000 tons prediction for controlled emission of silver in MSW combustion (Category II) system. Both of our Category II and III predictions for silver are reasonable and data found by others (displayed in Table 82-09-05.2.8) is not sufficiently convincing to warrant any change therefrom.

- Zinc - Our predictions for controlled emissions of zinc in both MSW & RDF combustion (Category II and III) systems, 1.76 and 1.00 lb/1000 tons respectively, are on the low side compared to the range of values found by others displayed in Table 82-09-05.2.8. The Cal Recovery Systems report on low concentrations of zinc in MSW combustibles reinforces confidence in our predictions, even if they are somewhat lower than were found by others.

vi. Table 82-09-05.2.9 Metals in MSW Combustibles

Table 82-09-05.2.9 is a tabulation of metals in MSW combustibles comparing the concentrations of these metals reported by Cal Recovery Systems for NSCC waste with data found by others. The information reported by Cal Recovery systems is useful in developing and corroborating the metal concentration and emission predictions for the non-criteria pollutant metals given in Tables 82-09-05.2.1 and 82-09-05.2.2.

f. Mercury as a Special Case

Because mercury is a very volatile metal (e.g. boiling point = 675°F), it might be expected that very little, if any of the metal would remain in the bottom ash. That is practically all of the mercury will be volatilized and carried off with the gas products of combustion either as vapor or adhering to fly ash particulates.

Based on a survey of mercury emission data available from Braintree, MA.; Hamilton, Ontario Canada; Gent, Belgium and WTE plants in Germany, reference "K" concludes that a conservative estimate of total mercury emissions from MSW is 6.4 lb/1000 tons MSW burned.

Cal Recovery Systems reports (See Table 82-00-05.2.9) mercury concentration in NSCC MSW combustibles to be 2.1 ppm which is higher than the 1.2 ppm average reported by others.

Reference "L" reports mercury gaseous emissions to be about 40 times the mercury particulate emissions. This may account for the wide range of data on mercury emissions reported to date in the literature, since many of the researchers fail to distinguish between vapor and solids phase emissions. Reference "L" ventures an estimate of mercury particulate emissions at 0.16 lb/1000 tons which is based on tests at the Braintree, MA plant, where it is known that the electrostatic precipitator there has failed to come up to expectations. Using a 99.5% efficient fabric filter bag house air pollution control device, we predict mercury particulate emission of 0.02 lb/1000 tons for MSW combustion (Table 82-09-05.2.1) and 0.016 lb/1000 tons for RDF combustion (Table 82-09-05.2.2).

A pertinent observation in managing mercury emission from combustion processes is to note the environmental trade-offs. As seen by reference to discussion above (par. c on Air quality Standards and par. d on Water Quality Standards), the assumed 99.5% collection efficiency for air pollution controls may concentrate too much mercury in the total ash (bottom plus fly ash) and thereby jeopardize California water quality standards being met by failure to comply with allowable WET ash leachate threshold levels. As can be seen by reference to the predicted and allowable atmospheric emissions given in par. c on Air Quality Standards, there appears to be more tolerance for larger emissions of mercury to the atmosphere than it being further concentrated in the collected fly ash, particularly for the RDF combustion systems. A possible means of reducing the mercury concentration level in collected ash is to add the RDF rejects to the ash before disposing the mixture in the landfill.

3. Hydrogen Chloride and Fluoride

a) Hydrogen Chloride (HCl)

Data on HCl emissions are given in reference "C", "D", "J", "K", "L" and "M".

MSW or RDF combustion would generate HCl gas due to thermal reaction of sources of hydrogen in the waste with plastics containing chlorine such as polyvinyl chloride and with other chlorine -

containing components such as common salt (sodium chloride).

Weighted average of Cal Recovery Systems data on chlorine in NSCC MSW combustibles, as reported in reference "B", indicates relatively high concentration - 1.25% on a moisture and ash-free basis. This may be compared with the 0.84% concentration previously estimated by Hayden-Wegman/Carollo. The 0.84% value is obtained after correcting the data displayed in Table 2 of Summary Report 82-09-03-3 to delete moisture and ash so that comparison is performed on a uniform moisture and ash-free basis.

Table 83-09-05.2.5 includes data on uncontrolled and controlled HCl emissions from MSW combustion without heat recovery (Category I) systems and also for RDF combustion with heat recovery (Category III) systems as well as for combustion of coal. This data is based on information from reference "J". Data on MSW combustion with heat recovery (Category II) systems is not given, but it may be assumed to agree with the Category I systems. Reference "K" states that only about half of the chloride in the waste is converted to HCl . This statement would probably be more accurate for Category I and II combustion sytems, but not as accurate for the Category III Systems where all of the chloride in the RDF is likely to be converted to HCl. The uncontrolled HCl emission data for Category III systems (3.2 lb/ton MSW) compared to that for Category I (1.4 lb/ton MSW both displayed in Table 93-09-05.2.5), would appear to corroborate this.

Reference "K" concludes that a reasonable estimate of the hydrochloric acid emissions is 3.4 lb/ton equivalent to 200 ppm. This agrees reasonably well with the 3.4 lb/ton ± 3.2 lb/ton estimate given in reference "L", although the variation off the average indicates higher levels than the 3.4 lb/ton average is possible and is probable for NSCC in view of Cal Recovery Systems data given in reference "B".

Controlled emissions of HCl is taken to be one-tenth of the uncontrolled emission, assuming the proposed quench tower/baghouse air pollution control equipment can achieve a HCl removal efficiency of 90%,

b. Hydrogen Fluoride (HF)

Data on HF emissions are given in reference "K", "L" and "M".

Very much like chlorine, the combustion process would chemically react hydrogen in the waste with fluorine from plastics and other sources to generate HF gas.

References "K", "L" and "M" predict uncontrolled emissions for HF to be in the range 0.06 to 0.10 lb/ton MSW or an average of 0.08 lb/ton MSW. This is less than the 3.4 lb/ton MSW uncontrolled emission estimate for HCl by a factor of about 40.

Weighted average of Cal Recovery Systems data on fluorine in NSCC

MSW combustibles as reported in reference "B", indicates a fluorine concentration of 0.007% on a moisture and ash free basis, this is less than the 1.25% concentration found for chlorine in NSCC MSW combustibles by a factor of about 180.

Assuming the high end of the estimated range for HF uncontrolled HF emissions, at 0.1 lb/ton MSW and assuming MSW combustion rate at 1000 tons per day, 365 days per year, the HF uncontrolled emissions is calculated to be 18.25 tons per year. Assuming a collection efficiency of 90%, controlled HF emissions would then be about 1.83 tons per year. This is less than the 3.0 tons per year maximum emission level permitted, which if exceeded, would mandate a prevention of significant deterioration (PSD) review.

Another analytical approach might be to assume that HF emissions would be less than HCl emissions by a factor of 180, equvalent to the ratio of the concentration of fluorine in MSW combustibles relative to chlorine, as reported by Cal Recovery Systems. Referring to Table 83-09-05.2.5, HCl controlled emissions is estimated at 0.140 lb/ton for Category I and possibly Category II combustion systems, whereas HCl controlled emissions is estimated at 0.320 lb/ton for Category III RDF combustion systems. Calculated tons per year of HF for the Category III RDF combustion system is then as follows:

$$\frac{0.320\text{ lb}}{\text{ton}} \times \frac{1\text{ ton}}{2000\text{ lb}} \times \frac{1}{180} \times 365{,}000\,\frac{\text{tons}}{\text{yr}} = 0.32\,\frac{\text{tons}}{\text{yr}}$$

This is still less than the 3.0 tons per year maximum emission level permitted for fluorides and therefore the PSD review should be waived.

4. Sulfuric Acid Mist

Reference "K" states little data is available on emissions of sulfuric acid mist, but based on a measurement taken on the Harrisburg, PA mass burn waterwall furnace suggests it is 1.6% of the SO_2 emission rate. On the basis of a 2.4 lb/ton rate for SO_2, sulfuric acid emission rate of 0.04 lb/ton is calculated. Collection will occur at high efficiency (99.5%) at the baghouse where it will be neutralized by unreacted lime from the dry scrubber. Controlled emission rate for sulfuric acid mist would then be 0.04 lb/ton (1-0.995) = 0.0002 lb/ton.

Assuming 1000 tons per day MSW combustion rate, 365 days per year, the tons per year of sulfuric acid mist emitted is calculated as follows:

$$\frac{0.0002\text{ lb}}{\text{ton}} \times \frac{1\text{ ton}}{2000\text{ lb}} \times 365{,}000\,\frac{\text{tons}}{\text{yr}} = 0.037\,\frac{\text{tons}}{\text{yr}}$$

This is less than the 7.0 tons per year maximum emission level permitted for sulfuric acid mist and therefore the PSD review should be waived.

5. Hydrogen Sulfide, Reduced Sulfur & Reduced Sulfur Compounds

These compounds are oxidized by the combustion process to SO_2 and SO_3 which are collected by the proposed dry scrubber air pollution control equipment; SO_2 at 85% efficiency and SO_3 (which is a fine droplet) at 99.5% efficiency.

6. Asbestos

Reference "K" states no data were found for asbestos emissions. Reference "N" confirms that size of emitted asbestos particles are relatively large and are amenable to high efficiency collection (99.9% plus) in proposed dry scrubber/baghouse air pollution control equipment.

7. Aldehydes (RCHO)

Reference "L" estimates aldehydes atmospheric emissions as follows:

0.07 lb/ton MSW

This is equivalent to:

70 lb/1000 ton MSW

8. Carboxylic Acid (RCOOH)

Reference "L" estimates carboxylic acid (RCOOH) atmospheric emissions as follows:

0.15 lb/ton MSW

This is equivalent to:

150 lb/1000 ton MSW

9. Vinyl Chloride Manomers (VCM)

References "K", "L" and "M" all conclude that vinyl chloride manomers are combustible and would be oxidized to carbon dioxide, water and hydrogen chloride (HCl) gas in the furnace atmosphere. The HCl gas formed in the VCM combustion process is accounted for in paragraph 3 (a) above.

10. Polynuclear Aromatic Hydrocarbons (PAH)

Two reference sources, "K" and "J" provide emission data on polynuclear aromatic hydrocarbons (PAH).

Reference "K" notes that PAH are common products of incomplete combustion of carbonaceous fuels and have been found in the emissions from many sources, including MSW combustion facilities. Reference "K" does not identify all of the PAH compounds but states that pyrene, fluoranthene and benzoanthracene were major constituents in many cases. Considering the wide variation at the available data, reference "K" has selected an average value of 10 lb/1000 tons MSW as being representative.

Reference "J" provides more specific emission data relative to PAH and points out the considerable reduction in PAH emissions in RDF combustion (Category III) systems relative to the MSW combustion without heat recovery (Category I) systems. No data is given on the MSW combustion with heat recovery (Category II) systems, although it may be expected to approximate the Category I emissions.

11. Polychlorinated Biphenyls (PCB)

Reference "K" reports PCB emissions having been found in trace amounts in several municipal waste-to-energy plants (e.g. Chicago NW, Dade County and Braintree). These emissions result from incomplete destruction of traces of PCB's found in the waste feed. Since the manufacture and distribution of PCB's is now prohibited, the amounts found in the refuse, and therefore the amount in the emissions, can be expected to decline in the future. Considering the available data, reference "K" suggests a reasonably conservative value for estimating PCB emissions to be 0.13 lb/1000 ton.

12. Dioxins and Furans

Traces of polychlorinated dibenzo-para-dioxins and dibenzofurans (dioxins and furans) have been identified in the emissions from a number of municipal incinerators abroad and in the U.S. (Reference "K").

Concern for these pollutants evolved in the late 1970's when analytic techniques were developed to measure these trace pollutants in the parts per trillion (10^{-12}) range. (Reference "M"). The measurement is not a simple task. It requires considerable sophistication to collect representative stack samples, extract dioxins from particulates, and separate dioxins from its isomers. The final identification of the 2,3,7,8-TCDD isomer (considered the most toxic of all dioxins and furans) is by gas chromatography–mass spectrometry and requires extremely skilled personnel.

Several theories have been proposed to account for the presence of dioxins and furans in the waste combustion plant emissions.

- they may be present in the feed and pass through the incinerator undestroyed,
- they may be formed from precursors such as chlorinated phenols, chlorinated benzenes or PCB's present in the feed or
- they may be formed by the reaction of traces of chlorine present in the feed with complex organics formed in the combustion process

a) Dioxins

Emission data, culled from the literature, is given as follows:

- Nashville, TN (Reference "M")

  A single particulate sample collected from the stack of the municipal waste incinerator at Nashville, Tenn., by Dow Chemical Co. The level of 2,3,7,8-TCDD in this sample was reported to be 0.4 ng/g. (0.4 x 10^{-9} g/g).

- Northern Italy and Europe (Reference "M")

  Sample of total TCDD obtained and analyzed in Northern Italy and Europe. Values ranged from 0.065 to 10 ng/g in the fly ash.

- EPA Data (Reference "M")

  Recent EPA samples and analysis of gaseous and particulate) stack effluents from waste incinderators in the USA. The stack values ranged from not detectable to 3.5 ng/m^3 (3.5 x 10^{-9} g/m^3).

- Battelle Report (Reference "K")

  Battele analyzed data from Dow Chemical Company as well as the data reported from Ontario and Europe and concluded that the average content of 2,3,7,8-TCDD in fly ash was 0.22 ng/g and that 2,3,7,8-TCDD represented 5% of the total TCDD content of fly ash. Battelle did not include the recent EPA data, other than to provide some dioxin vapor phase emission data. Battelle noted that the emissions reported for the Dutch incinerators are considerably higher than the other reported emissions (TCDD=54 vs 5.8 ng/g for ESP fly ash and 100 vs. 2 ng/g for stack particulates). Considering the available data, Battelle concluded that the best estimate of TCDD emissions possible is 1 x 10^{-9} to 500 x 10^{-9} lb/ton of refuse burned and that total dioxin emissions are possibly a factor of 10 higher. The emission estimated for the very toxic isomer 2,3,7,8-TCDD was 0.5 x 10^{-9} lb/ton of refuse burned. This was based on a 0.22 ng/g concentration of 2,3,7,8-TCDD in the fly ash relative to a 4.4 ng/g concentration of total TCDD in the fly ash (approximately 5% of 10 x 10^{-9} lb/ton = 0.5 x 10^{-9} lb/ton).

- Arthur D. Little Report (Reference "L")

  A.D. Little analyzed the European data on TCDD emissions and came to the conclusion that the amount of 2,3,7,8-TCDD emitted per ton of refuse burned was 0.034 x 10^{-6} lb/ton. The 2,3,7,8-TCDD isomer was estimated to be 10% of the TCDD content.

  Reference "L" includes emission data for other species of dioxins as well as for the 2,3,7,8-TCDD and TCDD as follows:

Dioxin Species	Emission
2,3,7,8-TCDD	34 x 10^{-9} lb/ton
TCDD	340 x 10^{-9} lb/ton
P5CDD	900 x 10^{-9} lb/ton
HCDD	1550 x 10^{-9} lb/ton
H7CDD	1550 x 10^{-9} lb/ton
OCDD	350 x 10^{-9} lb/ton

- Overview Report (Reference "O")

  This report states a resource recovery plant burning 1500 tons per day of MSW would emit 0.06 oz. of 2,3,7,8-TCDD dioxins per year. (This is equivalent to 6.85 x 10^{-9} lb/ton).

Comparative data on 2,3,7,8-TCDD emissions from the references "K", "L", and "O" are then as follows:

Reference	2,3,7,8-TCDD Emission
"K"	0.50 x 10^{-9} lb/ton
"L"	34.00 x 10^{-9} lb/ton
"O"	6.85 x 10^{-9} lb/ton

Reference "O" also states that recent test data has shown that 98% of the generated dioxins that form in the combustion process are sorbed on collected fly ash and bottom ash and that only 2% is emitted to the atmosphere. This would indicate total ash (fly ash and bottom ash) amounts to 49 times the ash emitted to atmosphere. Reference "O" furthermore states that the fly ash and bottom ash can be safely placed in modern landfills since dioxins have a very low solubility in water and will therefore have a minimal leachate problem.

b) Furans

Reference "L" provides emission data for species of chlorinated dibenzofuranes (furans) as follows):

Furan Species	Emission
TCDF	520 x 10^{-9} lb/ton
P5CDF	1080 x 10^{-9} lb/ton
HCDF	1810 x 10^{-9} lb/ton
H7CDF	1280 x 10-9 lb/ton
OCDF	160 x 10^{-9} lb/ton

13. Pesticides and Herbicides

Concentrations of pesticides and herbicides in North Santa Clara County MSW combustibles, as determined by sampling survey and laboratory measurements are given in Table III-9 of Cal Recovery Systems Report 83-01 (Reference "B").

Summary data is given in Table 83-09-05.2.11.

Atmospheric emissions due to combustion of perticides and herbides in the waste are already accounted for in the analyses made for the criteria and non-criteria atmospheric (stack) emissions described to date. The following analyses will account for the pesticides and herbicides that may be incompletely burned in the furnaces and which may report to the bottom ash.

a) MSW Combustion

Based on 87.7% of NSCC MSW being combustible (on a dry basis), and facility throughput of 822 TPD_7 wet MSW @ 25% H_2O (0.75 x 822 = 617 TPD_7 dry), pesticides and herbicides (P_1 P_2 & H) processed along with MSW is the product of P_1 P_2 & H concentrations and the MSW combustibles throughput, as follows:

$$*(837 + 4733 + 496) \times 10^{-9} \times 617\ TPD_7 \times 0.877$$

$$= 6066 \times 10^{-9} \times 541\ TPD_7$$

$$= 0.00328\ TPD_7\ P1\ P_2\ \&\ H,\ \text{dry basis}$$

The 822 TPD_7 wet MSW @ 25% H_2O is reduced to 180 TPD_7 residue, dry basis (See Table 9**).

The residue is expected to contain:

5% combustible and
0.2% putrescible materials.
(See Outline Specification**, page 2-12).

The putresible material production rate is computed as follows:

$$0.002 \times 180\ TPD_7 = 0.3600\ TPD_7$$

This putrescible material in the residue is calculated as a percentage of the incoming MSW combustibles, dry basis, as follows:

$$\frac{0.3600}{0.75 \times 822 \times 0.877} \times 100 = 0.0666\%$$

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* From Table 83-09-05.2.11
** From Hayden-Wegman/Carollo Report No. 82-09-03-3

The total pesticides and herbicides are assumed to be incinerated in the furnace at the same efficiency as the MSW combustibles.

Thus the total pesticides and herbicides input, amounting to 0.00328 TPD$_7$ Pl P$_2$ & H, dry basis, would be reduced to the following:

$$0.00328 \times 0.000666 = 2.18 \times 10^{-6}\ \text{TPD}_7\ P_1\ P_2\ \&\ \text{H dry basis}$$

Maximum concentration of total pesticides and herbicides in the residue is then:

$$\frac{2.18 \times 10^{-6}\ \text{TPD}_7\ P_1\ P_2\ \&\ \text{H, dry basis}}{180\ \text{TPD}_7\ \text{Residue, dry basis}}$$

$$= 12.1 \times 10^{-9} = 12.1\ \text{ppb}$$

The 6066 ppb maximum concentration of total pesticides and herbicides in MSW combustibles is then seen to be reduced to 12.1 ppb maximum concentration of pesticides and herbicides in the residue.

The calculation, given above, neglects the reacted lime products (e.g. Ca SO$_4$) of the flue gas desulfurization system, amounting to 90 TPD$_7$. (See Table 9, Report 82-09-03-3).

If the 90 TPD$_7$ is added to the 180 TPD$_7$ residue, total residue is 270 TPD$_7$, dry basis, and the resultant maximum concentration of pesticides and herbicides (P$_1$ P$_2$ & H) in residue is then computed as follows:

$$\frac{2.18 \times 10^{-6}\ \text{TPD}^7\ P_1\ P_2\ \&\ \text{H, dry basis}}{270\ \text{TPD}_7\ \text{Modified Residue, dry basis}}$$

$$8.1 \times 10^{-9} = 8.1\ \text{ppb}$$

The 6066 maximum concentration of total pesticides and herbicides, in MSW combustibles is then seen to be reduced to 8.1 ppb maximum concentration of pesticides and herbicides in the modified residue.

b) RDF Combustion

RDF manufactured, corresponding to 822 TPD$_7$ wet MSW @ 25% H$_2$O and 83.3% (dry basis) recovery rate, is as follows:

$$= 0.833 \times 0.75 \times 822\ \text{TPD}_7$$
$$= 514\ \text{TPD}_7\ \text{RDF, dry basis}$$

Pesticides and Herbicides (P$_1$ P$_2$ & H) processed along with the MSW becomes part of the RDF. P$_1$ P$_2$ & H in the RDF is the product of P$_1$ P$_2$ & H concentrations and the RDF manufactured:

*$(837 + 4733 + 496) \times 10^{-9} \times 514\ \text{TPD}_7$

$= 6066 \times 10^{-9} \times 514\ \text{TPD}_7$
$= 0.00312\ \text{TPD}_7\ P_1\ P_2\ \&\ H$, dry basis

The 822 TPD_7 wet MSW @ 25% H_2O is initially reduced to 514 TPD_7 RDF, dry basis (643 TPD_7 wet basis @ 20% H_2O), which after combustion, is further reduced to 55 TPD_7 residue dry basis. (See Table 11**)

The residue is expected to contain:

5% combustible and
0.2% putrescible materials
(See Outline Specification**, page 2-56)

The putrescible material is computed as follows:

$$0.002 \times 55\ \text{TPD}_7 = 0.1100\ \text{TPD}_7$$

The putrescible material in the residue is calculated as a percentage of the RDF that is to be burned, dry basis as follows:

$$\frac{0.1100}{514} \times 100 = 0.0214\%$$

The total pesticides and herbicides ($P_1\ P_2$ & H) are assumed to be incinerated in the furnace at the same efficiency as the RDF.

Thus the total pesticides and herbicides input in the RDF, amounting to 0.00312 TPD_7 P & H, dry basis would be reduced to

$$0.00312 \times 0.000214 = 0.67 \times 10^{-6}\ \text{TPD}_7\ P_1\ P_2\ \&\ H \text{ dry basis}$$

Maximum concentration of total pesticides and herbicides ($P_1\ P_2$ & H) in the modified residue is then:

$$\frac{0.67 \times 10^{-6}\ \text{TPD}_7\ \text{P \& H, dry basis}}{55\ \text{TPD}_7\ \text{residue, dry basis}}$$

$$= 12.1 \times 10^{-9} = 12.1\ \text{ppb}$$

The 6066 ppb maximum concentration of total pesticides and herbicides in MSW combustible is then reduced to 12.1 ppb maximum concentration of pesticides and herbicides in the residue.

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* From Table 83-09-05.2.11
** From Hayden-Wegman/Carollo Report 82-09-03-3

The calculation, given above, neglects the reacted lime products (e.g. $Ca\ SO_4$) of the flue gas desulfurization system, amounting to 24 TPD_7, (See Table 11, Report 82-09-03-3).

If the 24 TPD_7 is added to the 55 TPD_7 residue, total residue is 79 TPD_7 and the resultant maximum concentration of pesticides and herbicides (P_1 P_2 & H) in modified residue is then computed as follows:

$$\frac{0.67 \times 10^{-6}\ TPD_7\ P_1\ P_2\ \&\ H\text{, dry basis}}{79\ TPD_7\ \text{modified residue, dry basis}}$$

$$= 8.5 \times 10^{-9} = 8.5 \text{ ppb}$$

The 6066 ppb maximum concentration of total pesticides and herbicides in MSW combustibles is then seen to be reduced to 8.5 ppb maximum concentration of pesticides and herbicides in the modified residue.

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TABLE 82-09-05.2.1
Estimated Average Non-Criteria Pollutant Metal Emissions From MSW Combustion

Group	Element	Symbol	(1) Fly Ash Uncontrolled		(2) Bottom Ash		(3) Total Ash = (1) + (2)		(4) Atmospheric Fly Ash Controlled @ 99.5%	
			*	ppm	*	ppm	*	ppm	*	ppm
I	Arsenic	As	2.11	52	5.37	12	7.48	15	0.01	52
I	Barium	Ba	42.27	1040	117.06	262	159.33	327	0.21	1040
I	Cadmium	Cd	3.58	88	2.11	4.7	5.69	12	0.02	88
I	Chromium	Cr	16.26	400	37.39	83	53.65	110	0.08	400
I	Lead	Pb	299.15	7360	139.82	313	438.97	900	1.50	7360
I	Mercury	Hg	4.71	116	–	–	4.71	9.7	0.02	116
I	Selenium	Se	0.33	8	0.16	0.4	0.49	1	0.002	8
I	Silver	Ag	4.55	112	2.28	5	6.83	14	0.02	112
II	Antimony	Sb	48.8	1200	42.30	95	91.04	187	0.24	1200
II	Beryllium	Be	0.01	0.2	0.40	0.9	0.41	0.8	4×10^{-5}	0.2
II	Cobolt	Co	6.50	160	13.01	29	19.51	40	0.03	160
II	Copper	Cu	17.88	440	1217.72	2724	1235.60	2533	0.09	440
II	Manganese	Mn	66.66	1640	396.70	887	463.36	950	0.33	1640
II	Molybdenum	Mo	1.95	48	17.56	39	19.51	40	0.01	48
II	Nickel	Ni	17.88	440	37.39	84	55.28	113	0.09	440
II	Thallium	Tl	0.10	2.4	6.40	14	6.50	13	49×10^{-5}	2.4
II	Vanadium	V	2.11	52	2.11	4.7	4.22	8.7	0.01	52
II	Zinc	Zn	352.80	8680	586.91	1313	939.71	1927	1.76	8680

Group I metals are classified Non-Criteria Pollutants by USEPA & CDOHS
Group II metals are classified Non-Criteria Pollutants by CDOHS only
USEPA = United States Environmental Protection Agency
CDOHS = California Department of Health Services
* = $\frac{\text{lb of metal emitted (dry)}}{\text{1000 tons MSW @ 25\% } H_2O}$
ppm = parts per million, concentration of metal in ash category (1), (2), (3) or (4), uncorrected for ash products of acid gas control system

HAYDEN-WEGMAN/CAROLLO
engineers

October 25, 1983

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TABLE 82-09-05.2.2
Estimated Average Non-Criteria Pollutant Metal Emissions From RDF Combustion

Group	Element	Symbol	(1) Fly Ash Uncontrolled		(2) Bottom Ash		(3) Total Ash = (1) + (2)		(4) Atmospheric Fly Ash Controlled @ 99.5%	
			*	ppm	*	ppm	*	ppm	*	ppm
I	Arsenic	As	1.95	51	4.88	51	6.83	51	0.01	51
I	Barium	Ba	35.93	944	99.50	1037	135.43	1011	0.18	944
I	Cadmium	Cd	2.60	68	1.46	15	4.06	30	0.013	68
I	Chromium	Cr	8.94	235	20.32	212	29.26	218	0.04	235
I	Lead	Pb	100.31	2637	46.99	490	147.30	1100	0.50	2637
I	Mercury	Hg	3.09	81	-	-	3.09	23	0.016	81
I	Selenium	Se	0.33	9	0.16	2	0.49	4	0.002	9
I	Silver	Ag	2.93	77	1.46	15	4.39	33	0.015	77
II	Antimony	Sb	45.03	1184	38.85	405	83.89	626	0.23	1184
II	Beryllium	Be	0.01	0.2	0.40	4	0.41	3	$4x10^{-5}$	0.2
II	Cobolt	Co	3.09	81	6.02	63	9.11	68	0.016	81
II	Copper	Cu	9.10	239	621.54	6475	630.64	4708	0.046	239
II	Manganese	Mn	33.49	880	200.14	2085	233.63	1744	0.17	880
II	Molybdenum	Mo	1.79	47	16.26	169	18.05	135	0.01	47
II	Nickel	Ni	8.94	235	18.53	193	27.47	205	0.04	235
II	Thallium	Tl	0.10	3	5.92	62	6.02	45	5x10	3
II	Vanadium	V	1.87	49	1.87	19	3.74	28	0.01	49
II	Zinc	Zn	197.05	5179	327.76	3417	524.81	3917	1.00	5179

Group I metals are classified Non-Criteria Pollutants by USEPA & CDOHS
Group II metals are classified Non-Criteria Pollutants by CDOHS only
USEPA = United States Environmental Protection Agency
CDOHS = California Department of Health Services
* = $\frac{\text{lb of metal emitted (dry)}}{\text{1000 tons MSW @ 25\% H}_2}$
ppm = parts per million, concentration of metal in ash category (1), (2), (3) or (4), uncorrected for ash products of acid gas control system

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TABLE 82-09-05.2.3 (Sheet 1 of 2)
California Waste Extraction Test (WET)
*Proposed Threshold Concentration Limits For
Hazardous Waste Classification of Ash Containing Non-Criteria Metals

Group	Element	Symbol	(1) TTLC Total Threshold Limit Concentration (ppm)	(2) STLC Soluble Threshold Limit Concentration (ppm)
I	Arsenic	As	500	5
I	Barium	Ba	10,000	100
I	Cadmium	Cd	100	1
I	Chromium	Cr	500	5
I	Lead	Pb	1,000	5
I	Mercury	Hg	20	0.2
I	Selenium	Se	100	1.0
I	Silver	Ag	500	5.0
II	Antimony	Sb	500	100
II	Beryllium	Be	75	7.5
II	Cobolt	Co	8,000	80
II	Copper	Cu	250	2.5
II	Manganese	Mn	No Limit Set	No Limit Set
II	Molybdenum	Mo	3,500	350
II	Nickel	Ni	2,000	20
II	Thallium	Tl	700	7
II	Vanadium	V	2,400	24
II	Zinc	Zn	2,500	25

*Data, subject to revision, provided by Gerry White, Analyst of the Office of Waste-to-Energy California Waste Management Board, Oct. 6, 1983 telephone communication for guidance only.

Group I metals are classified Non-Criteria Pollutants by USEPA & CDOHS
Group II metals are classified Non-Criteria Pollutants by CDOHS only
USEPA = United States Environmental Protection Agency
CDOHS = California Department of Health Services
ppm = parts per million, concentration of metal in ash

Table 82-09-05.2.3 (Sheet 2 of 2)
California Waste Extraction Test (WET)

(1) TTLC ppm concentration limits are set for the Nitric Acid Digestion Process test. If ash samples pass this test, no need to test for STLC limits.

(2) STLC testing to be performed only if TTLC ppm concentrations exceed TTLC threshold limits given in Table. STLC testing determines if a 0.2 molar solution of citrate buffer, having a pH of 4.5 will, in a 48-hour test, leach Non-Criteria metals from an ash sample in an amount to exceed STLC threshold limits.

(3) State Water Resources Control Board will rule if composite ash samples (e.g. combined fly ash and bottom ash) is allowed.

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TABLE 82-09-05.2.4
Comparison of Average Non-Criteria Pollutant Metal Emissions* from MSW Combustion

Group	Element	Symbol	"C" Washington D.C. SWRC #1 Cycl. Col./ESP 0.9 lb/ton		"D" Nicosia Tray Scrub'r	"E" Braintree ESP 2.7 lb/ton		"C" Alexandria Wet Baffle 5.6 lb/ton	
			**Fly Ash	Suspended	8 lb/ton	Inlet	Outlet	**Flyash	Suspended
I	Arsenic	As	59	310 (0.28)	200	120	57 (0.15)	40	210
I	Barium	Ba	3,200	990 (0.89)	220	400	340 (0.92)	2,800	890
I	Cadmium	Cd	185	1,900 (1.71)	1,500	1,100	480 (1.29)	42	1,100
I	Chromium	Cr	780	870 (0.78)	105	270	200 (0.54)	1,330	490
I	Lead	Pb	NR	78,000 (70.20)	69,000	NR	NR	40,000	97,000
I	Mercury	Hg	NR	NR	NR	NR	0.31 (8×10^{-4})	NR	NR
I	Selenium	Se	12	39 (0.03)	49	< 25	38 (1×10^{-4})	3.4	23
I	Silver	Ag	220	1,000 (0.90)	110	165	79 (0.21)	85	390
II	Antimony	Sb	580	2,400 (2.16)	1,600	2,200	1,600 (4.32)	270	2,400
II	Beryllium	Be	NR	NR	NR	< 0.15	≤ 0.16 (4×10^{-4})		
II	Cobolt	Co	27	5 (0.0045)	2	38	17 (0.05)	12	
II	Copper	Cu	950	1,500 (1.35)	1,700	1,800	1,600 (4.32)	980	2,000
II	Manganese	Mn	2,100	410 0.37)	270	770	330 (0.89)	4,300	1,500
II	Molybdenum	Mo	NR	NR	NR	43	37 (0.10)	NR	NR
II	Nickel	Ni	NR	170 (0.15)	79	NR	NR	740	200
II	Thallium	Tl	NR	NR	NR	1.8	1.6 (0.004)	NR	NR
II	Vanadium	V	NR	NR	NR	39	24 (0.06)	135	22
II	Zinc	Zn	240,000	140,000 (126)	110,000	> 10,000	> 10,000 (> 27)	10,800	120,000

Group I metals are classified Non-Criteria Pollutants by USEPA & CDOHS
Group II metals are classified Non-Criteria Pollutants by CDOHS only
USEPA = United States Environmental Protection Agency
CDOHS = California Department of Health Services
NR = Not Reported
* Metal emissions are given in ppm concentration of metal in total particulate emissions
ppm = parts per million unless noted
( ) = lb of metal emitted/1000 ton MSW
** Collected Fly Ash
"C", "D" & "E" denote references to literature. (See page v).

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TABLE 82-09-05.2.5
Emission Factors for TSP & HCl Based on Total Feed Material

	UNCONTROLLED*				CONTROLLED**			
Category	I	II	III	Coal	I	II	III	Coal
T S P lb/ton	25	20	134	128	0.125	0.100	0.670	0.640
HCl lb/ton	1.4	NA	3.2	0.4	0.140	NA	0.320	0.040

Category Definitions

I	-	Mass-fired MSW Combustion w/o Heat Recovery
II	-	Mass-fired MSW Combustion with Heat Recovery
III	-	RDF Combustion with Heat Recovery

T S P	Total Suspended Particulates
HCl	Hydrochloric Acid

Emissions given in lb of emission per ton of total feed:
MSW for Categories I & II
RDF for Catogory III

* Reference: An Evaluation of Emission Factors For
Waste-to-Energy Systems - Executive Summary
by G.M. Rinaldi, T.R. Blackwood,
D.L. Harris & K.M. Tackett
Monsanto Research Corp. Dayton, Ohio
Table 6 for TSP Uncontrolled Emissions)
Table 13 for HCl Uncontrolled Emissions)
29 May 1979
USEPA Contract No. 68-03-2550, Task II

** Assume Controlled Emissions as follows:
99.5% Efficiency for TSP
90.0% " " HCl

NA - No data available

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TABLE 82-09-05.2.6
Concentractions of Trace Elements in Uncontrolled Particulate Emissions

UNCONTROLLED CONCENTRATIONS ppm				
Element	Category I	Category II	Category III	Coal
Antimony	-[a]	260 - 620	0.4 - 10	7 - 20
Arsenic	-[a]	50 - 70	20 - 80	20 - 120
Barium	-[a]	270 - 540	-[a]	-[a]
Bromine	-[a]	420 - 2,400	-[a]	-[a]
Cadmium	-[a]	380 - 820	0.3 - 1.4	0.6 - 1.0
Chlorine	-[a]	>10,000	-[a]	-[a]
Chromium	-[a]	50 - 560	5 - 20	6 - 8
Cobolt	-[a]	10 - 100	0.6 - 2.0	0.4 - 1.5
Copper	-[a]	420 - 590	10 - 50	6 - 7
Iron	-[a]	970 - 1,090	700 - 2,410	2,350 - 2,800
Lead	-[a]	11,600 - 17,500	1,220 - 2,930	340 - 380
Manganese	-[a]	420 - 1,400	10 - 20	20 - 40
Nickel	-[a]	-[a]	3 - 20	6 - 20
Selenium	-[a]	<90	10 - 40	10 - 50
Silver	-[a]	110 - 200	-[a]	-[a]
Tin	-[a]	2,600 - 5,000	50 - 150	20 - 30
Zinc	-[a]	>10,000	860 - 3,770	180 - 560

[a] Data Not Available

Reference: An Evaluation of Emission Factors For
Waste-to-Energy Systems - Executive Summary
by G.M. Rinaldi, T.R. Blackwood,
D.L. Harris & K.M. Tackett
Monsanto Research Corp., Dayton, Ohio
(Tables 14, 15, 16 & 17)
29 May 1979
USEPA Contract No. 68-03-2550, Task II

Category Definitions: See Table 82-09-05.2.5

ppm = parts per million

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TABLE 82-09-05.2.7
Concentrations of Trace Elements in Controlled Particulate Emissions

	CONTROLLED CONCENTRATIONS ppm			
Element	Category I	Category II	Category III	Coal
Antimony	610 - 12,600	460 - 1,000	2 - 180	10 - 150
Arsenic	80 - 510	50 - 100	140 - 740	20 - 680
Barium	40 - 1,700	270 - 540	-[a]	-[a]
Bromine	320 - 6,700	350 - 1,200	-[a]	-[a]
Cadmium	520 - 2,300	670 - 1,150	0.2 - 10	2 - 8
Chlorine	99,000 - 330,000	>10,000	-[a]	-[a]
Chromium	70 - 1,800	130 - 260	60 - 100	30 - 40
Cobolt	2 - 30	5 - 50	4 - 40	3 - 30
Copper	970 - 6,800	620 - 800	50 - 280	30 - 40
Iron	1,700 - 18,000	2,000 - 2,130	6,940 - 17,300	13,200 - 18,200
Lead	50,000 - 155,000	18,100 - 34,200	4,470 - 18,400	1,050 - 1,790
Manganese	170 - 5.700	140 - 490	110 - 240	100 - 140
Nickel	40 - 440	-[a]	20 - 190	30 - 40
Selenium	10 - 120	<30	20 - 430	30 - 40
Silver	40 - 2,000	50 - 110	-[a]	-[a]
Tin	8,500 - 15,100	1400 - 5000	260 - 870	30 - 270
Zinc	47,000 - 240,000	>10,000	4,360 - 17,200	910 - 3340

[a] Data Not Available

Reference: See Table 82-09-05.2.6

Category Definitions: See Table 82-09-05.2.5

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TABLE 82-09-05.2.8

Controlled Emissions of Trace Elements

CONTROLLED EMISSIONS lb/1000 ton		
Element	Category II	Category III
Antimony	0.046-0.10	0.0013-0.121
Arsenic	0.005-0.01	0.094-0.496
Barium	0.027-0.054	-[a]
Bromine	0.035-0.120	-[a]
Cadmium	0.067-0.115	0.0001-0.0067
Chlorine	>1	-[a]
Chromium	0.013-0.026	0.040-0.067
Cobolt	0.0005-0.005	0.0027-0.027
Copper	0.062-0.080	0.034-0.188
Iron	0.200-0.213	4.650-11.591
Lead	1.810-3.420	2.995-12.328
Manganese	0.014-0.049	0.074-0.161
Nickel	-[a]	0.013-0.127
Selenium	<0.003	0.013-0.288
Silver	0.005-0.011	-[a]
Tin	0.140-0.500	0.174-0.583
Zinc	>1	2.921-11.524

Controlled Emissions in lb/1000 tons is product of data shown in Tables 82-09-05.2.5 and 82-09-05.2.7

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TABLE 82-09-05.2.9

Metals in MSW Combustibles - NSCC vs Others

(ppm)

Group	Element	Symbol	NSCC	Others
I	Arsenic	As	5.7	ND
I	Barium	Ba	110	170
I	Cadmium	Cd	<3	9
I	Chromium	Cr	19	55
I	Lead	Pb	50	330
I	Mercury	Hg	2.1	1.2
I	Selenium	Se	<0.4	ND
I	Silver	Ag	<2.5	3
II	Antimony	Sb	70	45
II	Beryllium	Be	<0.3	ND
II	Cobolt	Co	<5	3
II	Copper	Cu	423	350
II	Manganese	Mn	138	130
II	Molybdenum	Mo	<12.2	ND
II	Nickel	Ni	<16	22
II	Thallium	Tl	<4	ND
II	Vanadium	V	2.9	ND
II	Zinc	Zn	339	780

ND = No Data

NSCC data based on average ppm concentrations reported in combustible fraction of MSW from Cal Rec'y Syst. Inc. Report No. 83-01 "Laboratory Analysis of the Combustible Fraction of NSCC MSW" dated March, 1983 Table III-6 (weighted averages).

Others data based on average ppm concentrations of combustible fraction of MSW from Washington D.C., Baltimore, Howard and Montgomery Counties, Md., Tampa, FL and Tulsa, OK as measured at the Bureau of Mines Avondale Metallurgy Research Center in Maryland; "Sources of Metals in Municipal Incinerator Emissions" by Stephen L. Law and Glen E. Gordon, Table II, Environmental Science & Technology, April, 1979.

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TABLE 82-09-05.2.10

Polynuclear Aromatic Hydrocarbons (PAH) Emissions

EMISSIONS lb/1000 Ton		
PAH Species	Category I	Category III
Benzo(a) anthracene/chrysene	6.2	-
Benzo(b) fluoranthene	2.8	-
Benzo (ghi) perylene	3.2	-
BaP/BeP	1.5	1.5
Coronene	1.6	-
Fluoranthene	10.0	2.5
Indino (1,2,3, cd) pyrene	1.5	-
Perylene	1.5	1.5
Pyrene	12.0	0.76
Fluorene	-	0.76
1,2 - Benzofluorene and 2,3 - Benzofluorene	-	1.1

Reference: An Evaluation of Emission Factors for Waste-to-Energy Systems - Executive Summary by G. M. Rinaldi, T.R. Blackwood, D. L. Harris & K. M. Tackett, Monsanto Research Corporation, Dayton, Ohio. (Tables 18 and 19)
29 May, 1979
USEPA Contract No. 68-03-2550. Task II

Category Deninitions: See Table 82-09-05.2.5

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TABLE 82-09-05.2.11

Pesticides amd Herbicides Concentrations in NSCC MSW Combustibles

Processable Waste		Maximum Concentration, ppb (dry basis)					
		Pesticides				Herbicides (H)	
		Chlorinated (P_1)		Phosphate (P_2)			
Delivered By	% (1)	Lab.(2)	Ext.(3)	Lab.(2)	Ext.(3)	Lab.(2)	Ext.(3)
Rear Loaders	(33.6%)	426	143	5187	1742	545	183
Front Loaders	(44.6%)	1271	567	4963	2213	435	194
Debris Boxes	(21.8%)	583	127	3570	778	545	119
Composite	(100.0%		837		4733		496

Notes:

(1) % Distribution of Processable Waste amongst Rear Loaders, Front Loaders & Debris Boxes based on Summary of Average Daily Waste Quantities given in Table I of Authority 4/11/83 MEMO.

(2) Laboratory data on Maximum Concentration of respective pesticides and herbicides in sampled vehicled; Reference "B", Table III-9.

(3) Extension of Data Inputs (1) and (2) are derived by multiplication of respective % distributions and lab data on Rear Loaders, Front Loaders and Debris Boxes, and summing the respective products to obtain the composite waste characteristics indicated.

Exhibit A

Scope of Work

Leaching Characteristics of Ash in a Landfill Environment

Tasks

1. Pack columns with ash and start flow of municipal waste leachate or distilled water, as prescribed in plan.
2. Collect leachate samples twice weekly from the glass manifolds and from each column.
3. Analyze each leachate sample for the following:

Metals

Antimony
Arsenic
Barium
Beryllium
Cadmium
Chromium (total & Cr IV)
Cobalt
Copper
Lead
Mercury
Molybdenum
Nickel
Selenium
Silver
Thallium
Vanadium
Zinc

Minerals

Cations

Ammonia
Solium
Potassium
Calcium
Magnesium

Anions

Bicarbonate
Carbonate
Chloride
Sulfate
Nitrate (as N)
Fluoride
Hydroxide

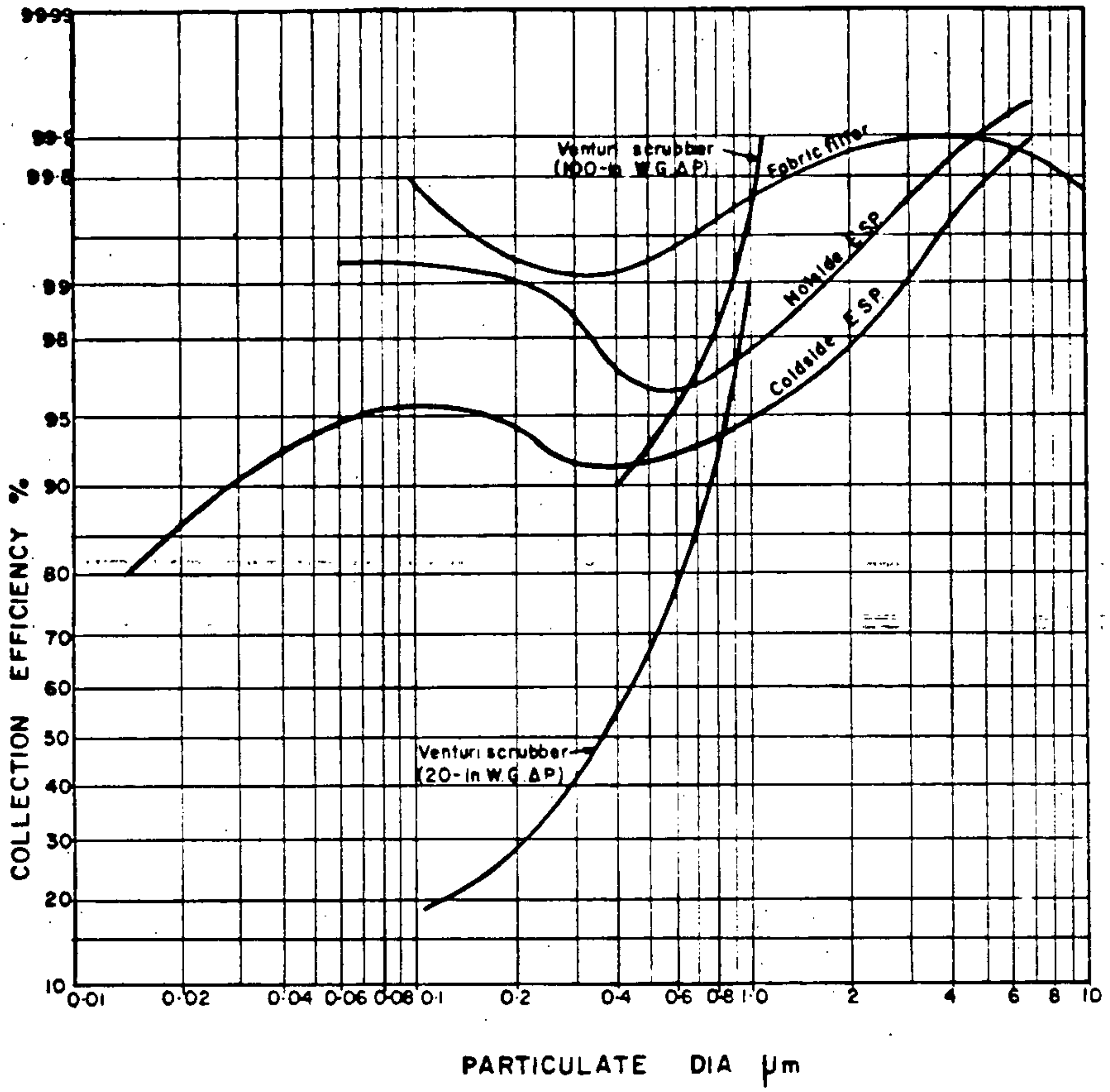
Additional

pH
Alkalinity
Total Hardness
Specific Conductance

A. Elemental analysis shall be conducted by using inductive coupled plasma-atomic emissions spectrometry (ICP) twice weekly and once every two weeks by atomic absorption spectroscopy (AA) for metallic elements.

B. Mineral analysis, pH, alkalinity, total hardness, and specific conductance shall be recorded twice weekly.

4. Monitor pH and Eh continuously at glass manifolds.
5. Record total volume over time of leachate and distilled water.
6. All ICP analyses completed and entered into Data Management System.
7. All AA analyses completed and entered into Data Management System.
8. Submit monthly reports to Project Manager.
9. Draft report to Project Manager.
10. Final report published and submitted to Project Manager.



FRACTIONAL EFFICIENCY CURVES FOR CONVENTIONAL AIR-POLLUTION CONTROL DEVICES

FIGURE. 1