Florida Department of Environmental Protection

Memorandum

TO:

THRU: Bruce Mitchell

FROM: William Leffler, PE

DATE: March 7, 2001

DAY 90

SUBJECT: Conrad Yelvington Distributors Inc. draft permit No 7770473-004-AC
Response to October 6 Request for Additional Information.

Background

Conrad Yelvington Distributors, Inc. (CYDI) is a dealer in construction aggregate with facilities throughout the state. Stephanie Brooks, P.E. is CYDI's consultant on the air permit issues. Solid waste issues are being independently handled by Alex Padva.

On April 19, 2000, CYDI submitted an application for a relocatable permit to allow its Powerscreen Chieftain 510 material classifier to be operated throughout the state of Florida. No specific material was specified on the application. CYDI's vice president for operations, William Thomas, III, indicated that the portable screener would be used throughout the state to "reclassify" sand and gravel as it was loaded or unloaded from rail cars or trucks. Within a few days prior to issuing a draft construction permit and intent to issue, it was learned that CYDI planned to use this machine to process spent abrasive blast media. This knowledge was a substantial variation from the reasonable assumption that the machine would be used for sand and gravel, but rather than deny the permit, a prohibition against processing hazardous waste including ABM was included as a special condition in the draft permit.

The public notice of the draft permit has never been published. CYDI requested an opportunity to submit additional material justify elimination of the special condition prohibiting ABM and hazardous waste.

In October CYDI submitted a short letter with projected air emissions of metals based on AP42 factors and TCLP laboratory tests. This submission precipitated an incompleteness letter, which is setout with the summaries of the applicants responses.

Application Insufficiencies and CYDI's Response

On March 6 we received a package of material from Stephanie Brooks, P.E. which was furnished in reply to Our October 6, 2000 incompleteness letter. Generally, the letter denies that spent ABM is a hazardous waste and suggests that the permit restrictions are unreasonable. The letter included the following attachments: (DEP Mail room stamp March 5, 2000)

Review of Response to Incompleteness Letter
Conrad Yelvington Distributors, Inc.
Application for use of portable screener for processing Spent Abrasive Blast Media

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1. Investigation of Separation, Treatment and Recycling Options for Hazardous Paint Blast Media Waste USACERL Technical Report 96/51, February 1996.

2. Recycling and Reuse Options for Spent Abrasive Blasting media and Similar Wastes Naval Facilities Engineering Service Center Technical memorandum TM 2178-ENV.

3. Historical Weather Data for the Tampa FL from Washington Post web site.

4. Storage Pile Emission Calculations based on Missouri DEQ Emission Inventory Questionnaire Form 2.8 Storage Pile Worksheet (including instructions).

5. MSDS from Virginia Minerals and Supplies, Inc regarding "Black Blast' Abrasives. Revised August 2, 1999.

6. Report of physical characteristics FDOT Aggregate system reflecting sieve analysis of "sample 1", reflecting 22.5 % passing 100 mesh and 10.5% passing 200 sieve.

7. "Typical Chemical Analysis" Black Sand-Boiler Slag, fax from Rinker Material, source of sample and sampling protocol not identified.

8. Report of Analysis, Southeastern Environmental; Laboratories November 17, 1999 regarding sample from HIS-Titusville, Submission no 9900160.

9. Report of physical characteristics FDOT Aggregate system reflecting sieve analysis of "sample 2", reflecting 21 % passing 100 mesh and 9.7% passing 200 sieve.

10. Report of Analysis, Southeastern Environmental; Laboratories February 23,2001 regarding unidentified sample, submission no 10006422 (Gross Analysis).

11. Report of Analysis, Southeastern Environmental; Laboratories February 23,2001 regarding unidentified sample, submission no 10006422 (Fines Analysis).

12. Report of Analysis, Southeastern Environmental; Laboratories February 23,2001 regarding unidentified sample, submission no 10006422 (SPLP Analysis).

13. Report of Analysis, Rinker Environmental Services, Inc., February 19, 1998 regarding sample 8920, (Black Sand), (Source "Rinker" blacked out with magic marker).

14. Report of Analysis, Rinker Environmental Services, Inc., February 19, 1998 regarding sample 8921, (Black Sand), (Source "Rinker" blacked out with magic marker).

15. Report of Analysis, Rinker Environmental Services, Inc., February 19, 1998 regarding sample 8922, (Black Sand), (Source "Rinker" blacked out with magic marker).

16. Report of Analysis, Rinker Environmental Services, Inc., February 19, 1998 regarding sample 8922, (Black Sand), (Source "Rinker" blacked out with magic marker).

17. Report of Analysis, Rinker Environmental Services, Inc., February 19, 1998 regarding sample 8924, (Black Sand), (Source "Rinker" blacked out with magic marker).

18. Report of Analysis. Advanced Analytical Laboratories, Inc., February 23,2001 regarding Gulf marine Repair unidentified sample, report No J001042, (TCLP Analysis.

19. Report of Analysis, Schneider Laboratories, Inc., June 6, 1999 Worth Contracting (Washington Terrace, St Petersburg), sample 33519, report No [illegible], (TCLP Analysis.

20. Printout from Virginia Materials web site. Screen or Mesh Size.

21. Printout from Virginia Materials web site. Examples of Cleaning Rates of Common Abrasives

22. Printout from Virginia Materials web site. Beneficial Reuse Program and attached Adobe Acrobat pamphlet Beneficial Reuse and Disposal of Abrasives Program

Detailed Response to Incompleteness Letter

Ms Brooks deals with the issues raised in the October 16, 2000 letter as follows: (A summary of the applicant's response in **BOLD** type follows each numbered item).

1. The analytical data provided with the amended application is not based on a statistically significant number of samples to reflect the probable maximum, and typical average, constituents of the material stream. The three sample analysis reports are not sufficient to form a reliable opinion as to the range of concentrations that may be attributable to spent ABM as a commodity.

Please provide statistically significant data on the chemical and physical characteristics of the spent ABM, including the chemical analysis reflecting the range, average, and standard deviation of mass concentrations in a statistically significant number of samples from each type of source or industry supplying spent ABM with respect to: Arsenic, Barium, Cadmium, Chromium, Copper, Iron, Lead, Nickel, Mercury, Selenium, Silver, Zinc, and any toxic anti-fouling paint compounds or volatile solvents that might be found in spent ABM recovered from shipyards.

SUMMARY OF RESPONSE: Answers contained in enclosures and two additional documents which form the basis of [applicant's] belief that so long as material does not fail TCLP or SPLP, it can be safely processed by CYDI without requiring additional onerous additional testing requirements or facilities for processing or storage. None of the attachments purports to be a comprehensive sampling or ABM or other slag products, nor are the few analysis provided correlated to any specific product or process relevant to the material to be processed.

2. The analytical data furnished does not reflect an appropriate test method. The TCLP related tests (EPA methods 1121, 1311, 6010B, 7470 and 7471A) are intended to measure the leaching potential of a sample. This leaching potential is not related to the mass concentration of the pollutants in the sample, nor in the dust or fine portion of the sample. The test results are expressed in milligrams of speculated solute per kilogram of sample. The TCLP tests and related lysimeter procedures are used to classify wastes based on their suitability for disposal in landfills, where contamination of groundwater, by percolation of rainwater through a waste layer,

is the critical consideration. Air pollution estimates must be based on the mass concentrations of the identified constituents in the spent ABM, and if possible, on the mass concentrations of the identified constituents in the fine portion (passing the 200 mesh sieve) of the spent ABM.

Please provide engineering data on the physical characteristics of each type of spent ABM to be processed, including a dry and wet sieve analysis to determine the portion of the sample passing the 100 and 200 mesh screens; a hydrometric/gravimetric analysis to determine the particle size distribution of the fine portion of a each type of spent ABM; and an atomic adsorption spectroscopy analysis of the gross sample and the fine portion to determine the relative fraction of heavy metals or toxic components that may be entrained in the air by the various material handling procedures and the vibrating screen. Please identify appropriate laboratory methods and standards for identification and quantification of heavy metals and toxic chemicals in the dust fraction of the spent ABM to be processed.

SUMMARY OF RESPONSE: Answers contained in enclosures and two additional documents which form the basis of [applicant's] belief that so long as material does not fail TCLP or SPLP, it can be safely processed by CYDI without requiring additional onerous additional testing requirements or facilities for processing or storage. Sieve analysis and additional testing was provided on allegedly similar material from alternate sources. The laboratory data is not sufficient to identify sample sources nor to establish that it is a statistically significant representation of all the classes of material the applicant proposed to process. Only a single laboratory sample (attachments 10, 11 and 12, included with the response purported to be an analysis of the same sample with respect to the criteria metals and their proportions in the gross sample, the fine portion of the sample and the leachable fraction which is the criteria for classification as a hazardous waste. The results provided by Rinker materials fail to specify the nature of the material (whether gross sample, fines or leachate) and none of the analytical data is presented offer any information regarding the range of concentrations and statistical probability of specific concentrations. See for comparison Carlson's and Townsend's papers identified to the applicant in question 4.

3. The Department has experienced difficulty in finding background information on the nature of the spent ABM that the applicant proposes to process, except that such material often contains significant levels of heavy metals and that it often contains significant quantities of toxic chemicals, the environmental significance and fate of which are uncertain.

The Department has identified a thesis by Jenna Jambeck Carlson, *Leaching Characteristics and Assessment of Abrasive Blasting Waste from Ship Maintenance Facilities and Sandblasting Contractor Sites,* University of Florida (1998), and a paper by Tim Townsend, *Best Management Practices for Waste Abrasive Blast Media*, Florida Center for Solid and Hazardous Waste Management (1998) which are provided to the applicant, (Both of these references were prepared from the same data sets). These documents are focused landfill disposal and incorporation of waste ABM into soil cement or road construction material, but provide some guidance on the range of mass concentrations based on limited sampling.

SUMMARY OF RESPONSE: Not directly addressed. Presumably the technical papers which are identified above as attachments 1 and 2 are intended to address these concerns. Calculations are furnished for wind and operational erosion losses to a storage pile based on 1000 tons per day, a 0.3 acre pile and 255 days per year operation. (Does not the wind blow 365 days per year?)

4. The applicant has not provided any generally acceptable industry profile nor identified any other facilities which process similar materials in the manner proposed by the applicant. The Department has identified Virginia Materials, 3306 Peterson St., Norfolk, VA 23509 as a larger producer of spent ABM for recycling in the production of portland cement. We are aware that Rinker Materials, Inc., Tarmac America, Inc., and Florida Rock Industries, Inc., incorporate slag based spent ABM in their portland cement kiln feedstock.

Please provide any additional references to management practices, sampling protocol, and material batch acceptance standards that will give the Department 'reasonable assurance' that the permittee will not process hazardous spent ABM, store hazardous spent ABM on its sites, nor create any unsafe condition or health hazard by processing spent ABM on any of its sites.

SUMMARY OF RESPONSE: CYDI states that it does not accept ABM which fails the TCLP determination for hazardous waste.

5. There are other environmental issues that cause us to inquire about the status of permitting and compliance issues that would be addressed by other divisions of the Department, by the Hillsborough County Environmental Protection Commission and by The U.S. EPA. Please provide information on the following issues:

(a) Please describe measures will be taken to meet industrial waste water, solid waste, hazardous waste, and groundwater permitting rules; or,
(b) Please provide copies of the appropriate permits that have been issued or exemption letters that have been obtained.

SUMMARY OF RESPONSE: CYDI acknowledges that air permit does not grant immunity from haz-waste issues. A. Padva has been engaged to resolve solid waste issues.

6. Please comment on the following aspects of a management plan for the handling, processing, and storage of spent ABM:

(a) Why a concrete floor should not be required for the storage of spent ABM to prevent leaching and loss of water percolating through the storage piles.
(b) Why an enclosed structure should not be required to contain and recover dust from the proposed screening, or spent ABM storage operations.
(c) Why a continuous mist dust suppression system should not be employed within an the enclosed structure.
(d) Why a negative pressure dust collection system coupled with a air pollution collection device such as a cyclone, baghouse or scrubber, should not be required to eliminate airborne transport of dust containing heavy metals or toxic chemicals associated with processing of spent ABM.

SUMMARY OF RESPONSE: The power screen is intended to operate as a portable any pollution will be temporary rather than continuous. Any requirement for enclosure, negative air pressure and concrete floor is onerous. Virginia Materials urges appropriate ABM Slag storage directly on the ground with a tarp cover.

7. Please specify an emission estimating protocol to quantify the loss of heavy metals and toxic components of spent ABM by wind erosion from storage piles process activities and work yard activities, and that entrainment caused by vehicular traffic at the processing facility.

SUMMARY OF RESPONSE: this item is not directly addressed. Suggests that air emissions be extrapolated from Storage pile losses calculated according to the Missouri Inventory Questionnaire (attachment 3)

8. Please describe the standard, or proposed procedure, to be taken in the event of any spill of spent ABM, whether on the facility, or in transit, either before of after processing, including alternative disposal plans, appropriate agencies to be notified, availability of containment equipment, and personnel training.

SUMMARY OF RESPONSE: CYDI states that it does not accept any material not passing TCLP. Off spec or unmerchantable materials will be hauled to a landfill for disposal.

9. Please identify the disposal options and disposal site(s) for any 'off spec' or unmerchantable fraction of the spent ABM, including that portion passing the finest screen (tailings) and that portion retained on the coarsest screen (scalpings), which would presumably contain trash and shop waste from the producer of the spent ABM.

SUMMARY OF RESPONSE: Not specifically identified see response to 8 above.

10. Please identify the sites around the state of Florida where the applicant contemplates using the transportable Powerscreen classifier to process spent ABM. Please provide the potential counties and the UTM coordinates or latitude and longitude for all such sites.

SUMMARY OF RESPONSE: Hillsborough County (within particulate maintenance area) Duval and Orange Counties, (more precise location not identified).

(unnumbered last paragraph) The Department will resume processing your amended application after receipt of the requested information. No additional fee is required. Rule 62-4.050(3), F.A.C., requires that all applications for a Department permit must be certified by a professional engineer registered in the State of Florida. This requirement also applies to responses to Department's requests for additional information of an engineering nature. Permit applicants are advised that Rule 62-4.055(1), F.A.C., requires applicants to respond to requests for information within 90 days, with processing time on the permit tolled during the actual time taken for the response. If you have any questions, please call me at (850) 921-9522.

SUMMARY OF RESPONSE: Response is 156 days after request, but within 30 days of written warning of intention to recommend denial if response not forthcoming. The response letter and supporting attachments were not submitted under Professional Engineers Seal

Other Related Issues, Processing of TECO Ash

Review of Response to Incompleteness Letter
Conrad Yelvington Distributors, Inc.
Application for use of portable screener for processing Spent Abrasive Blast Media

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On January 31, 2001 Bob Butera an engineer with Southwest District Solid Waste section advised:

> this facility (CYDI) is leasing property from (Hardaway Corporation), a [groundwater cleanup] case located adjacent to a solid waste permitted facility on Cone Road in Tampa. The site is taking bottom ash from Tampa Electric - Big Bend Facility (operating w/o a solid waste permit) until yesterday. I visited the site and they informed me they are mixing the spent abrasive together with the bottom ash (12 loads per day) and shipping it to Rinker in Miami. The residuals from the spent abrasives fines (look pretty nasty) are stockpiled on the ground without containment just like the bottom ash. They have volunteered to stop accepting the ash as they have scheduled a preapplication with the district next week for a transfer station permit

A meeting was held at on Thursday February 1st at 10:00 am to discuss the consultant's design concept and solid waste rules requiring a transfer station permit. Air regulatory staff including Hillsborough County EPC, were encouraged to participate.

A temporary operating agreement was reached with the Southwest District solid waste program to allow CYDI to continue to handle ash from TECO upon the condition that the ash containment area be waterproofed against the possibility of leaching, and that arrangements be made for the proper disposal of leachate from the ash piles. The ash piles will be kept surface wet to suppress fugitive dust. The screening unit is not to be used for ash processing.

The Division of Air resource management has not issued any permit to Conrad Yelvington Distributors, inc. for the use of a powerscreen classifier for the processing of coal slag or "spent abrasive blast media" (ABM). A draft air construction permit was issued on August 11, 2000 based on an application for the use of such a powerscreen in various aggregate yards operated by CYDI but it has never been advertised, The draft AC, in addition to requiring advertising and testing for final construction and operating permits, expressly prohibited the processing of spent ABM and any form of hazardous waste.

Brooks & Associates, Inc.
Engineering and Environmental Consulting

February 28, 2001

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Mr. William Leffler, PE
Permitting Engineer
Division of Air Resources Management
Department of Environmental Protection
3900 Commonwealth BLVD
Tallahassee FL 32399-3000

RE: Response to RAI 7770473-001-AC

Dear Mr. Leffler:

Brooks & Associates, CYDI and Alex Padva, Ph.D. have been involved in developing the answers to your request. The items will be taken out of order but will provide information for all.

Items 8 and 9 CYDI does not accept any material that has not passed hazardous waste screening tests. Therefore there is no need for extraordinary methods of dealing with spills. The off-spec or unmerchantable portions of the spent ABM are hauled to a landfill for disposal. The handling of the material may change depending on the Reuse memo that is being generated by the Solid and Hazardous Waste Sections.

Item 10 The power screen will potentially be used in Hillsborough County at the current location, Duval County at a location to be determined and Orange County at a location to be determined.

Item 5 Additional permitting if required by the reuse memo will be handled on an as needed basis. CYDI and Brooks & Associates are well aware of the rule that getting an air permit does not grant immunity from other permitting requirements. A. Padva, Ph.D. is involved in resolving solid waste issues associated with the spent ABM.

Item 6 As the power screen is designed to be a portable unit, the requirement of a negative pressure dust collection system with air pollution control system along with an enclosed structure seem to be more applicable to permanent and therefore a continuous source of air pollution rather than a temporary one. The same comment extends to a continuous mist suppression system. The material's moisture content of 0.4% which is similar to the moisture content of crushed stone. A concrete floor is less onerous but still seems extraordinary for a slag material that isn't considered hazardous. Please see Virginia Material's Reuse document that allows for storage of material on the ground with a berm around it and a tarp to cover it for short-term storage.

Item 4 CYDI does not accept spent ABM that fails the TCLP determination for hazardous wastes. Each source of material is tested prior to being transported to the site. If the material fails, it isn't accepted and the generator of the material has to dispose of it instead of it being processed and then reused as kiln feed. Your rather broad request for " reasonable assurance that the permittee will not .... nor create any unsafe condition or health hazard by processing spent ABM on any of its sites" can only be answered by CYDI does not intend to create an unsafe condition or health hazards for the general population or its workers by processing any kind of material. In support of this statement please find a copy of the MSDS for similar material from Virginia Materials and copy of that company's beneficial reuse program document.

Item 3 Emission estimates for the piles. See Emissions inventory questionnaire from State of Missouri for Storage Piles.

Tampa area Emission Factors based on this sheet are:

Wind erosion	0.53 lb PM10 per acre of storage pile per day
Activity	0.41 lb PM 10 per ton

Using the chemical composition of Spent Coal Slag Media from Technical Memorandum TM-2178-ENV RECYCLING AND REUSE OPTIONS FOR SPENT ABRASIVE BLASTING MEDIA AND SIMILAR WASTES published in April 1996, we find that the weight percent of metals varies and that the TCLP results are very similar to the results of TCLP performed on our samples. Therefore, we can extrapolate that the weight percent of metals will be similar to the report's results.

Metal Emissions (example)

	Wind Erosion lb PM10 – day/acre	Activity lb PM10/ton
Pb	0.0027	0.0021

Processing 1000 tons per day from a pile that occupies about 3/10 of an acre and 255 days/yr operation.

Pb	0.0001 tpy	0.27 tpy

Items 1 and 2 The answers are contained in the enclosures. We have provided sieve analyses on our material, additional testing on our material and on similar from alternate sources. We have identified two additional technical documents which we use to base our belief that as long as the material does not fail TCLP or SPLP, it can safely be processed by CYDI without requiring onerous additional testing requirements or facilities to be built for processing and storage.

Should you have any questions, please call me at (954) 796-1987.

Thank you for your assistance,

Stephanie S Brooks, PE
Stephanie S. Brooks, PE

Enclosures: Historical Weather Data for Tampa FL

Typical Chemical Analysis for Black Sand/Boiler Slag

MSDS for "Black Blast Abrasives"

Sieve Analyses

SPLP and TCLP data on Gross and Fine Samples

Additional Test Results for Black Sand

Screen or Mesh Size information

Beneficial Reuse and Disposal of Spent Abrasives Program

Emissions Inventory Questionnaire

Recycling and Reuse options for Spent Abrasive Blasting Media and Similar Wastes

Investigation of Separation, Treatment, and Recycling Options for Hazardous Paint Blast Media Waste

Cc: Mr. William Thomas, CYDI
Mr. Frank Milton, CYDI
Mr. Alex Padva, Ph.D.

**US Army Corps
of Engineers**
Construction Engineering
Research Laboratories

USACERL Technical Report 96/51
Febrauary 1996

Investigation of Separation, Treatment, and Recycling Options for Hazardous Paint Blast Media Waste

by
Jeffrey H. Boy, Timothy D. Race, and Keturah A. Reinbold

U.S. Army depot depaint operations generate over 4 million kg per year of contaminated paint blast media wastes. A variety of abrasive blast media are used. Spent blast media wastes are often determined to be hazardous when tested for characteristic metals using Toxicity Characteristic Leaching Procedure (TCLP) Method 1311. Disposal of contaminated blast media is regulated by the Environmental Protection Agency as well as state and local authorities. Because environmentally sound disposal of hazardous waste is very expensive, the Army could significantly benefit from cost-effective treatment processes that would render paint blast media wastes nonhazardous, or reduce waste bulk by isolating and disposing separately of hazardous components. The objective of this work was to investigate technologies that might significantly mitigate this Army hazardous waste disposal problem.

Most of the technologies investigated either failed to meet acceptable TCLP levels for hazardous metals content, or failed to meet Army disposal requirements. However, based on a review of several commercially available services, it is recommended that Army depot depaint operations consider processing hazardous blast media waste through properly regulated contractors that offer safe, effective, and economical stabilization, fixation, and recycling technologies. Due consideration should include an appropriate legal review of liability and regulatory issues.

Foreword

This research was performed for the U.S. Army Environmental Center under Project 4A262720D048, "Industrial Operations Pollution Control Technology"; Work Unit NN-UT4, "Hazardous Waste Separation from Paint Blast Media." The technical monitor was Ronald P. Jackson, ENAEC-TS-D.

The work was performed by the Materials Science and Technology Division (FL-M) of the Facilities Technology Laboratory (FL), and the Natural Resources Assessment and Management Division (LL-N) of the Land Management Laboratory (LL), U.S. Army Construction Engineering Research Laboratories (USACERL). Dr. Alan W. Moore is Acting Chief and Donald F. Fournier is Acting Operations Chief, CECER-FL. William D. Goran is Chief and Dr. William D. Severinghaus is Acting Operations Chief, CECER-LL.

Patricia A. Kemme of the Analytical Chemistry Laboratory (CECER-UL-I) is acknowledged for her efforts on this project. Part of the work was performed under contract by Mr. John Bukowski and Dr. Xiaofeng Zhu of the Center for Cement Composite Materials at the University of Illinois at Urbana-Champaign.

COL James T. Scott is Commander and Acting Director of USACERL, and Dr. Michael J. O'Connor is Technical Director.

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List of Tables and Figures

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Figures

1 Introduction

Background

Abrasive blasting has become the preferred method of paint removal at Army maintenance facilities (PEI 1990). Army facilities generate over 4 million kg per year of contaminated paint blast media wastes from paint removal operations. Depending on the paint system and substrate, a variety of abrasive blast media may be used for paint removal. Most blasting operations have a recirculation system that removes spent blast media particles too small for efficient paint removal. The resulting blast media wastes are often determined to be hazardous when tested for characteristic metals using the Environmental Protection Agency (EPA) Toxicity Characteristic Leaching Procedure (TCLP) Method 1311. The typical contaminants found in spent media are barium, cadmium, chromium, and lead. Disposal of contaminated blast media is regulated by the Federal government through, for example, the *Resource Conservation and Recovery Act of 1976* (RCRA, PL 94-580, as amended) as well as by state and local authorities. Because environmentally sound disposal of hazardous waste is very expensive, the Army could significantly benefit from cost-effective treatment processes that would render paint blast media waste nonhazardous, or reduce waste bulk by isolating and disposing separately of hazardous components. The U.S. Army Construction Engineering Research Laboratories (USACERL) was tasked to investigate technologies that might significantly mitigate this hazardous waste disposal problem.

Objective

The objective of this work was to evaluate and identify cost-effective processes for separating, breaking down, immobilizing, or recycling hazardous compounds in paint blast media wastes generated by Army depot depaint operations.

Approach

The Air Force Engineering and Service Laboratories previously evaluated disposal and recovery methods for plastic media blasting (PMB) waste in a multiphase research program. The results of these studies (Tapscott, Blahut, and Kellogg 1988; Jermyn and Wichner 1991) were reviewed by the researchers to avoid duplication of effort and to eliminate previously evaluated and rejected technologies.

Personnel from the U.S. Army Construction Engineering Research Laboratories (USACERL) conducted site visits to Army maintenance facilities where abrasive paint blast operations were performed. These included Red River Army Depot, TX; Sacramento Army Depot, CA; Corpus Christi Army Depot, TX; Tooele Army Depot, UT; Anniston Army Depot, AL; and Letterkenny Army Depot, PA. USACERL personnel observed these operations and retrieved samples of blast media waste for laboratory analysis and testing.

Waste processing techniques investigated in the laboratory by USACERL included cement stabilization and acid digestion. USACERL personnel also evaluated the chemical stabilization and fixation processes used by Red River Army Depot, and performed independent laboratory tests to verify the suitability of the process. Additional studies were performed by contractors to investigate microbiological digestion and low-temperature ashing (incineration). USACERL personnel also visited Army and Air Force maintenance facilities using lease recycle programs, and evaluated those programs.

Mode of Technology Transfer

The technologies recommended in this report may be suitable for use by a variety of Department of Defense installations including all Army, Navy, Air Force, Marine, Corps and National Guard installations involved in the repair and renovation of equipment. Technology transfer will be through the U.S. Army Environmental Center (USAEC) and the Army Center for Technical Excellence (CTX) for Mechanical Depaint (Industrial Operations Command), Anniston Army Depot, AL. The findings of this research were presented and published in the technical proceedings of the following symposia: the 17th Army Environmental Research and Development Conference (Boy et al., June 1993), the American Ceramic Society annual meeting (Bukowski et al., April 1994), and the 87th Annual Air and Waste Management Conference (Boy et al., June 1994). Results were also published in the peer-reviewed journal *Hazardous Waste & Hazardous Materials* (Boy et al. 1995).

Units of Measure

This report principally uses standard international (SI) units of measure. Where any U.S. standard unit appears, a conversion factor is provided on first use.

2 Abrasive Blasting Processes, Media, and Waste

Selection of Abrasive

Selection of the size and type of abrasive that most effectively and economically produces the desired surface finish depends on several variables including:

- the nature of the substrate being cleaned, including surface hardness
- the degree of corrosion that may have developed before blast cleaning
- the nature of any previous paint or coating system
- the type of surface finish desired.

Steel shot is a common abrasive blast media used on heavy steel structures. Steel shot consists of spherical particles of steel created by granulating a molten stream of metal with water, air, or other methods. Cast steel grit consist of angular particles produced by crushing steel shot.

Nonmetallic abrasive blast media are listed in Table 1[*]. Sand has been replaced by a number of alternatives because of the respiratory hazards associated with free silica. Inorganic substitutes in use are garnet, alumina (aluminum oxide), silicon carbide, and glass beads. Agricultural media include ground walnut shells or apricot pits, and wheat starch or corn starch products.

A number of plastic blast media available for paint removal are summarized in Table 2. The harder and larger particles generally provide faster paint removal but are also more likely to damage to the underlying substrate. Therefore, on sensitive equipment, softer materials (with slower removal rates) are often used.

The types and distribution of media used at two Army maintenance facilities are shown in Table 3. The wide variety of abrasive blast media used at various Army maintenance facilities makes it difficult to develop one optimum waste separation technique for universal Army use.

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[*] Tables and figures in this report may be found at the end of the chapter in which they are first referenced.

Substrate Considerations

Grey (1993) reviewed the advantages and disadvantages for the use of plastic blast media. Although paint removal from hard steel substrates, used in support equipment, proved to be very successful by plastic media blasting (PMB), it did not produce the surface roughness that normally occurred with grit blasting. A more aggressive blast media such as steel shot or mineral abrasives will produce the appropriate roughness.

Clad-type aluminum alloys are often used in structures exposed to severe environments such as those found in many military aircraft components. This clad aluminum consists of a corrosion-prone structural aluminum core with an outer cladding layer of a more corrosion-resistant aluminum alloy. Because this outer layer is soft, it is prone to damage during paint removal. The use of Type V acrylic plastic media has been found to inflict less damage to this outer layer than Type II urea formaldehyde plastic media (Grey 1993; Pauli 1993).

Paint removal from composites during maintenance has generally been difficult. Grey (1993) reported that Type V acrylic media or specialized commercial media (Type VI) may be used with operating conditions that remove minimal amounts of the polymer matrix. Alternately, the use of wheat starch for paint removal on air frames, has been accepted by several major aerospace manufacturers. The use of agricultural and starch abrasive media continues to grow (Pauli 1993). A variety of agricultural based abrasive blast media have been approved for use by the military (Military Specification [Mil] G-634C), Table 4.

Waste Characterization

Waste treatment technologies for PMB waste have been previously evaluated by the U.S. Air Force Engineering and Services Center and Oak Ridge National Laboratory (Tapscott, Blahut, and Kellogg 1988; Jermyn and Wichner 1991). Paint blast media waste is generated by in-line classification equipment that rejects all material passing through a 60 mesh screen. This corresponds to particles smaller than 250 μm. Size measurements performed by sieving indicated a highly variable particle size distribution, generally between 38 and 250 μm. However, photomicrographs revealed many particles of a much smaller size, ranging between 1.0 and 0.1 μm. In addition, they reported that photomicrographs showed numerous extremely small particles, which they attributed to the stripped paint, that were adhered to the large degraded PMB particles. They further concluded that dry separation treatments which seek to reduce waste volume by removing the paint particle from the degraded PMB waste would likely be ineffective due to the adhesive forces between the small paint particles and the larger blast media particles.

Toxic Characteristic Leaching Procedure

The Toxicity Characteristic Leaching Procedure (TCLP) is the means mandated by the EPA for determining the toxicity of a hazardous material (Federal Register, 13 June 1986). Method 1311, the procedure used in this research, is outlined below:

1. A 100 gram sample of the waste is crushed to pass through a 9.5 mm standard sieve
2. A 5 gm portion of the sample is used to determine the extraction solution
    - A 5 gm sample is weighed into a 250 ml beaker
    - 99.5 ml of deionized water is added to the 5 gm sample, stirred vigorously for 5 minutes, and the pH of the solution is determined
    - If the pH is <5.0, then Extraction Solution A is used—an acetic acid-sodium acetate buffer solution (pH = 4.93 +/- 0.05)
    - If the pH is >5.0, then Extraction Solution B is used—an acetic acid solution (pH = 3.88 +/- 0.05). (Note: this is the only point at which the pH is determined in the TCLP.)
3. A 100 gram sample is transferred to a plastic bottle and 2 liters of the appropriate extraction solution is added.
4. The sample is rotated for 18 +/- 2 hours.
5. The sample is filtered and the extraction fluid retained for chemical analysis.

Chemical Analysis

As part of this study, USACERL personnel retrieved samples of paint blast media waste from operations at several Army depots. The results of the laboratory testing and analysis are presented in Appendix A, Tables A1–A10.

The principal RCRA metal contaminants in paint blast media waste were found to be barium (Ba), cadium (Cd), chromium (Cr), and lead (Pb). The blast media waste samples failed the TCLP extraction test for Cd, Cr, and Pb. No sample failed TCLP for Ba. The principal difficulties of this work were: (1) the wide variety of blast media types utilized at the various facilities (see Table 3) and (2) the wide variability of contaminant concentration for a given waste from any individual facility. This variability arose from the diversity of waste, sources, and paint systems being removed at the time of waste sampling.

Table 1. Physical data on nonmetallic abrasives.

Media	Hardness (Mohs)	Shape	Sp. Gr.	Bulk Density (g/ml)	Color	Fee Silica	Degree of Dusting	Reuse
Naturally Occurring Abrasives								
Silica								
Silica	5	Round	2 to 3	100	White	90 +	High	Poor
Mineral	5 to 7	Round	3 to 4	125	Variable	< 5	Medium	Good
Flint	6.7 to 7	Angular	2 to 3	80	Lt. Gray	90 +	Medium	Good
Garnet	7.5	Angular	4	145	Pink	nil	Medium	Good
Zircon	47.5	Cubic	4.5	185	White	nil	Low	Good
Novaculite	4	Angular	2.5	100	White	90 +	Low	Good
By-Product Abrasives								
Slags								
Boiler	7	Angular	2.8	85	Black	nil	High	Poor
Copper	8	Angular	3.3	110	Black	nil	Low	Good
Nickel	8	Angular	2.7	85	Black	nil	High	Poor
Walnut Shells	3	Cubic	1.3	45	Black	nil	Low	Poor
Peach Shells	3	Cubic	1.3	45	Black	nil	Low	Poor
Corn Cobs	3	Angular	1.3	45	Black	nil	Low	Good
Manufactured Abrasives								
Silicon Carbide	9	Angular	3.2	105	Black	nil	Low	Good
Aluminum Oxide	8	Blocky	4.0	120	Black	nil	Low	Good
Glass Beads	5.5	Spherical	2.5	100	Black	nil	Low	Good

Source: From SSPC's *Steel Structures Painting Manual, Volume Two, Systems and Specifications*, 6th Edition ©1991. Used with permission of the Steel Structures Painting Council (SSPC), 40 24th Street, 6th Floor, Pittsburgh, Pennsylvania 15222-4643, USA.

Table 2. Comparative properties of plastic media used in paint stripping.

Type	Composition	Thermal Properties	Hardness (Barcol)	Paint Stripping Rate	Effect On Substrate	Applications
I	Polyester	Thermoset	34 to 42	Slow	Low	Thin sections metal Alloys
II	Urea Formaldehyde	Thermoset	54 to 62	Acceptable	Medium	Non-critical thin section metal alloy
III	Melamine-Formaldehyde	Thermoset	64 to 74	Fast	Severe	Steel and other ferrous alloys
IV	Phenol-Formaldehyde	Thermoset	54 to 62	Fast	Very Server	Steel and other ferrous alloys
V	Acrylic	Thermo-plastic	46 to 54	Acceptable	Low	Thin section metal alloys & composites
VI	Poly-allyl-diglycol-carbonate	Thermo-plastic	20 to 30	Acceptable	Very Low	Thin section metal alloys & composites

Source: Grey 1993.

Table 3. Summary of abrasive paint operations at selected Army depots.

Media	Anniston		Letterkenny	
	10^3 Kg	%	10^3 Kg	%
Walnut Shells	240	15	1306	80
Coal Slags	827	51		
Magnesium/Iron Silicates	400	24		
Plastic Media			82	5
Glass	80	5	26	1
Aluminum Oxide	40	2.5		
Steel Shot	40	2.5	226	14
Sand			5	>1
Totals	1627	100	1645	100

Source: PEI 1990.

Table 4. Grain, abrasive, soft, for carbon removal.

Type	Media	Approved Use
I	Apricot Pits	Aircraft jet engine or general purpose use
II	Pecan Shells	General purpose use only
III	Black Walnut Shells	Aircraft jet engine or general purpose use
IV	Corn Cobs	General purpose use only
IV	Rice Hulls	General purpose use only
VI	English walnut shells, apricot pit shells, or a mixture of the two	Aircraft jet engines only
VII	Peach Pits	Aircraft jet engines or general purpose use

Source: Military Specification (MIL) G-5634C.

3 Physical Separation Processes for PMB

The Air Force Engineering and Service Laboratories (Tapscott, Blahut, and Kellogg 1988) evaluated cost-effective and environmentally sound disposal and recovery methods for PMB waste residues. The physical, chemical, and thermal treatment processes evaluated are summarized in Table 5. The knowledge gained in this and subsequent work was used to avoid duplication of effort by USACERL and to eliminate previously evaluated and rejected technologies.

Dry Separation Processes

Waste samples were separated into various particle size fractions using a series of progressively finer sieves. Tapscott, Blahut, and Kellogg (1988) concluded that because the hazardous and nonhazardous particulate are very close in size, screening cannot efficiently separate the waste into regulated and nonregulated components.

Electrostatic separation was also evaluated in the Air Force study. Electrostatic separation involved injecting the PMB waste into a high-voltage direct-current electrical field. After exposure to the electric field, material falls to either side of a gate: material more attracted to the electric field falls to one side of the gate and material less attracted falls to the other side of the gate. Tapscott, Blahut, and Kellogg (1988) reported that the process sometimes resulted in fractions that differed greatly in metal concentrations, but the results were erratic and separation was insufficient.

Liquid Media Separation

Tapscott, Blahut, and Kellogg (1988) evaluated liquid density separation as a means to separate PMB waste into metals-rich and metals-depleted fractions. A ferric chloride solution showed little separation while potassium iodine solution showed modest success in generating a float-rich fraction. Carbon tetrachloride (CCl_4) worked very well, giving sink materials containing most of the metal contaminants. However, owing to the cost and toxicity of this material, handling and disposal would be difficult and expensive. A separation was also attempted with the less toxic chlorofluorocarbon (CFC) 113 ($CF_2ClCFCl_2$). The analysis showed little separation.

Additional work was performed on the liquid density separation of the hazardous component from PMB waste as summarized in Table 7 (Jermyn and Wichner 1991). Visual evidence indicated good physical separation of Type V PMB and paint solids using a potassium carbonate (K_2CO_3) solution with a density of 1.30 g/ml. Agitation (ultrasonic vibration and pumped circulation stirring) and centrifugation were found to aid physical separation. Addition of a surfactant (Turgitol) had only a marginal effect. Potassium carbonate solution had a deleterious chemical effect as lead and chromium leached into the liquid. Lead and barium were found to be more leachable by means of TCLP as the paint solids deteriorated. Calcium bromide solution (1.3 g/ml) also yielded good physical separation of Type V PMB and paint solids. Yellow coloration of the liquid occurred, indicating the presence of chromium in solution. However, calcium bromide solution (1.60 g/ml) yielded good physical separation of Type V PMB and paint solids. No liquid coloration occurred. Sucrose solutions (density 1.25) yielded poor separation. The researchers found that liquid density separation generally resulted in significant leaching of the metal contaminants into the liquid solution so the liquid itself was rendered a characteristic hazardous material.

Conclusions on the feasibility of liquid media separation (Jermyn and Wichner, 1991) included the following:

- The possibility of leaching pigment metals (particularly chromium) into solution, detracts from the liquid media separation concept
- Some water-based liquids render the pigment metals more susceptible to TCLP extraction; in some cases marginally hazardous PMB waste becomes more hazardous
- It would be difficult to develop a liquid media separation process for a broad range of paint and PMB densities that would provide effective separation and not leach metals
- Since there appeared to be no suitable organic liquid for such a process, the concept of liquid media density separation of PMB paint solids should not be further pursued.

Table 5. Results of Air Force survey of waste treatment options.

Treatment Method	Positive	Negative	Recommendations
Incineration	High degree of volume reduction	Regulatory difficulty, costly, hazardous off gases	Not recommended
Chemical treatment		Produces hazardous liquid wastes	
Charring	Good waste reduction	Produces flammable off gas, regulatory difficulty	
Encapsulation in plastic	Passed EP toxicity test	High cost	
Encapsulation in cement	Passed EP toxicity test	Adds to waste volume, good formulation not found	
Density Separation*	Good waste reduction	Only hazardous liquids (CCl_4 worked)	Recommended Best Approach
Electrostatic precipitation		Erratic results	
Aerodynamic classification		Poor waste concentration	

Source: Tapscott, Blahut, and Kellogg 1988.

Table 6. Metal ion analysis on density separated fractions.

		Total Metals			EP Toxicity Test		
	Fraction % of Total	Pb (ppm)	Cd (ppm)	Cr (ppm)	Pb (mg/L)	Cd (mg/L)	Cr (mg/L)
Ferric Chloride							
Float		400	200	380			
Sink		350	608	434			
Potassium Iodide Soln.							
Input		590	67	625	<0.2	1.08	18.0
Float	82%	590	67	625	<0.2	0.38	0.5
Sink	18%	230	25	150			
Carbon Tetrachloride							
Input		1400	60	1200	0.14	0.006	0.12
Float	94%	140	40	140	0.014	0.004	0.014
Sink	6%	17200	400	17100	1.72	0.040	1.71
CFC - 113							
Input		790	152	1700	<0.2	1.70	28.1
Float	28%	1390	248	2430	<0.2	1.97	64
Middle	16%	885	131	1480	<0.2	1.00	23
Sink	57%	660	191	1190	<0.2	10.4	20.5

Source: Tapscott, Blahut, and Kellogg 1988.

Table 7. Liquid density separation test.

PMB Waste	Liquid Solution	Liquid Density (g/ml)	Details	Results
Type V	Sucrose	1.25	Centrifuge (~500 G)[a]	No separation (with or without wetting agent
Type V	Potassium Carbonate	<1.25	Centrifuge (~550 G)	No separation (with or without wetting agent)
Type V	Potassium carbonate	1.30	Centrifuge (~550 G)	Good separation (with or without wetting agent) Liquid colored yellow[b]
Type V	Potassium carbonate	1.30	1 Gravity settling, ultrasonic vibration and pumped circulation trials	Good separation (no wetting agent) Liquid colored yellow[b]
Type V	Calcium Bromide	1.30	1 Gravity settling, ultrasonic vibration and pumped circulation trials	Good separation (no wetting agent) Liquid colored yellow[b]
Type II	Calcium Bromide	1.30	1 Gravity Settling	Good separation Clear Liquid

Source: Jermyn and Wichner 1991.

[a] Indicates acceleration in terms of gravity units

[b] Indicates extraction of chromium.

4 Low-Temperature Ashing

Objective of the Technology

Low-temperature ashing (LTA) involves subjecting the blast media waste to mild oxidation conditions at moderately elevated temperatures. Preliminary work was performed by Oak Ridge National Laboratory (ORNL) on LTA for the treatment of hazardous plastic blast media waste for the Air Force Engineering and Service Center (Jermyn and Wichner 1991). Weight loss measurements of a sample of Type V acrylic blast media heated to 500 °C in air resulted in a 95 percent reduction of the sample mass. The potential advantages of LTA includes a high degree of waste volume reduction. The ashing procedure reduces the waste volume down to the nonoxidizable portion of the waste (i.e., the pigment and the contaminants) and removes by vaporization the nonhazardous plastic portion that comprises at least 90 percent of the waste. The LTA treatment process is relatively robust. It does not depend on the microscopic properties of the waste (such as particle size) or pigment nature. Compared to high temperature incineration, LTA would be more likely to contain the hazardous components more completely within the ash than in the off-gas. The ash product of LTA would require further treatment before disposal. However the LTA ash to be disposed would be reduced to 5 percent of its original mass.

LTA Applicability and Process

LTA would be an appropriate candidate for treatment of blast media wastes that undergo significant decomposition upon heating in the temperature range of 500-600 °C. LTA would not be suitable for mineral or slag abrasives that have significantly higher melting points, nor for glass beads that melt without significant decomposition or volume reduction. In addition to Type V (acrylic) and Type III (urea formaldehyde) plastic media, LTA was investigated as possible treatment process for ground walnut shell blast media.

The experimental work, performed by ORNL, focused on determining certain thermal properties of virgin paint blast media used at Army maintenance facilities. The experiment involved three principal tests: (1) thermogravimetric (TG) analysis, i.e., weight loss as function of temperature at a controlled heating rate, (2) measurement of the vaporized gas volume, and (3) characterization of significant volatile organic compounds (VOCs) generated during LTA. The objective was to test the suitability of LTA process against Army requirements. The procedures used by ORNL in conducting these tests are detailed in Appendix B.

Results

Thermal Decomposition

The acrylic paint blast media was essentially converted into a gaseous state, with no residue, during TG analysis. During sample heating, slight mass loss was observed beginning at about 133 °C. Mass loss became rapid at about 250 °C, and began to level off at around 350 °C. Solid acrylic material, which is a light white powder at room temperature, was essentially converted into gasses at temperatures above 420 °C (Figure 1). During TG analysis a weight decrease of 99.75 percent was recorded.

Thermal analysis of urea formaldehyde blast media yielded a more complex mass loss curve, and a residue was left even after heating the media to 1200 °C. The weight change was 87.7 percent (as shown in Figure 2). Observable mass loss began to occur at 65 °C and continued until about 780 °C, with major inflection points at 258 °C, 360 °C, 520 °C, and 678 °C.

The ground walnut shell blast media, which also contained some fruit pits, was also subjected to TG analysis. Sample mass loss began at about 55 °C and ended at about 670 °C. Less than 1 percent of the original mass was left over as residue; the total weight change was 99.02 percent (Figure 3).

Volume of Gases Produced

During LTA experiments to determine the gaseous volume generated by paint blast media samples, significant amounts of smoke were produced. A light-colored smoke was observed during ashing of the acrylic material. Generated smoke from ground walnut shell and urea formaldehyde was denser and darker in color. The ground walnut shell media produced a significant amount of dark liquid condensate. Calculated gaseous combustion exhaust volumes, from integrated mass flow rate data (Table 8) were used to estimate the undiluted significant VOC concentrations in the smoke (Tables 9, 10, and 11). Gaseous volumes data also were plotted versus time (Appendix B). Note that the major portion of combustion effluent is generated during the first minute or two of a timed LTA experiment. With the urea formaldehyde media, off-gassing continued at a slower rate for approximately 20 minutes. Since the ashing process is exothermic, the experimental setpoint temperature of 575 °C was slightly exceeded during combustion experiments. Actual transient temperatures approaching 620 °C were observed briefly during ashing before dropping back to the setpoint temperature.

Characterization of Significant Volatile Organic Compounds (VOCs) Produced

Clearly, products generated by the combustion of paint blast media represents a very complex mixture. The reconstructed total ion chromatograms from a chamber blank and for the vapor phase samples generated from the combustion of paint blast materials of the ground walnut shell, acrylic, and urea formaldehyde media are presented in Appendix B. Because of the complex nature and overly abundant constituents present in each of the vapor phase samples, the effort was focused on the identification of major components. Those components represent a chromatographic area equal or greater than 1.0 percent of the total chromatographic area.

Electron impact (EI) mass spectral data obtained from thermal desorption (TD) and gas chromatography/mass spectroscopy (GC/MS) analyses were used to carry out identification. Identification of most components was based on the best match of the mass spectral pattern with those provided in the *Eight Peak Index Mass Spectra*, 3d ed. (Royal Society of Chemistry 1983). For components without a match (or with a poor match), chemical structures were postulated to best correlate with the observed fragmentation patterns. Tables 9–11 list compounds that have been tentatively identified in the sample traps. Their estimated quantities (μg/L), as determined based on the response factor of d_6-benzene, were also listed. Chemical nomenclature in the tables refer to general chemical structures, which may include structural isomers with the same chemical formula.

The ground walnut shell media generated predominantly oxygen-containing compounds upon combustion. The abundance of components with furan, phenol, and catechol moieties may be derived from lignin polymer. Because this sample trap was used with a mass range of 35–500 atomic mass units (amu), the water peak was not detected.

The acrylic blast material produced abundant quantities (approximately 5 μg/L) of methyl methacrylate (methyl ester of methacrylic acid) from the combustion process. Other compounds containing methacrylic acid moiety were also detected. Significant amounts of water accumulated on the sample trap most likely came from the combustion products or from the ambient air being used to purge the combustion chamber during sampling. Although the sorbent materials in triple absorbent traps (TST) are hydrophobic, excess amounts of water are retained on the traps despite purging with 1 liter of helium prior to TD step.

The urea formaldehyde blast material is made of polymerized urea formaldehyde (98 percent) with alpha cellulose filler. The hazardous decomposition products or byproducts for this material as listed in the Material Safety Data Sheets (MSDS) are smoke, carbon monoxide, carbon dioxide, formaldehyde, and hydrogen cyanide. Significant amounts (0.5 μg/L) of carbon dioxide [mass/atomic number (m/z) = 44] have been detected in the air peak along with m/z 28 ions, which is a molecular ion for either carbon monoxide or nitrogen. The selective ion mode was used to obtain mass chromatograms of m/z 27 and 26 (the two most abundant ions for hydrogen cyanide) to search for the presence of hydrogen cyanide. Experimental details are presented in Appendix B. A similar procedure was employed to search for the presence of formaldehyde; none of the early eluting components exhibited the expected characteristic ions generated from formaldehyde. It was determined through consultations that Carbosieve S-II sorbent in the TST is not expected to retain formaldehyde. In addition, Carbosieve S-III is not an ideal sorbent for hydrogen cyanide. Other major components found in the trap include alkyl nitriles, alkylamides of various chain lengths, and compounds with alcohol and furan moieties.

Summary of LTA Results

Temperatures required for media waste volume reduction differ depending on the waste type being processed. Treatment of acrylic media would probably involve effective, almost total reduction of the polymer at temperatures under 400 °C. Processing the ground walnut shell media and especially the urea formaldehyde media would most likely require a cost-benefit analysis to determine the degree of volume reduction desired as compared to the energy expenditure necessary to accomplish it. Temperature inflection points may indicate good management control points in the waste volume reduction process. Mass loss rates, detailed above, may have implications for waste processing time and power consumption during different steps in the LTA process. Weight loss measurements on virgin media indicated that the weight of urea formaldehyde media decreased by 87 percent at 800 °C, and ground walnut shell media decreased in weight by more than 99 percent at 700 °C.

Discussion

LTA is basically low-temperature incineration. Although the experimental design used triple sorbent traps to capture volatile organics, the sorbent was not effective in trapping formaldehyde and hydrogen cyanide. These components may be produced during LTA and perhaps were present in the combustion effluent of urea formaldehyde media even though the triple sorbent traps used did not effectively capture those compounds. Both formaldehyde and hydrogen cyanide are classified as hazardous air pollutants under the Clean Air Act. The thermal decomposition of the agricultural media generated phenol, and the polymerized urea formaldehyde generated toluene—also classified as hazardous air pollutants. Any volatilized heavy metal contaminants would be classified as hazardous air pollutants.. The difficulty of obtaining regulatory approval for any incineration process makes it unlikely that this process could successfully be implemented at Army facilities.

In addition to the air pollution concerns, most of the heavy metal contaminants would be expected to remain in the ash residue, and would require further treatment disposal. Use of LTA at Army maintenance facilities is not recommended at this time.

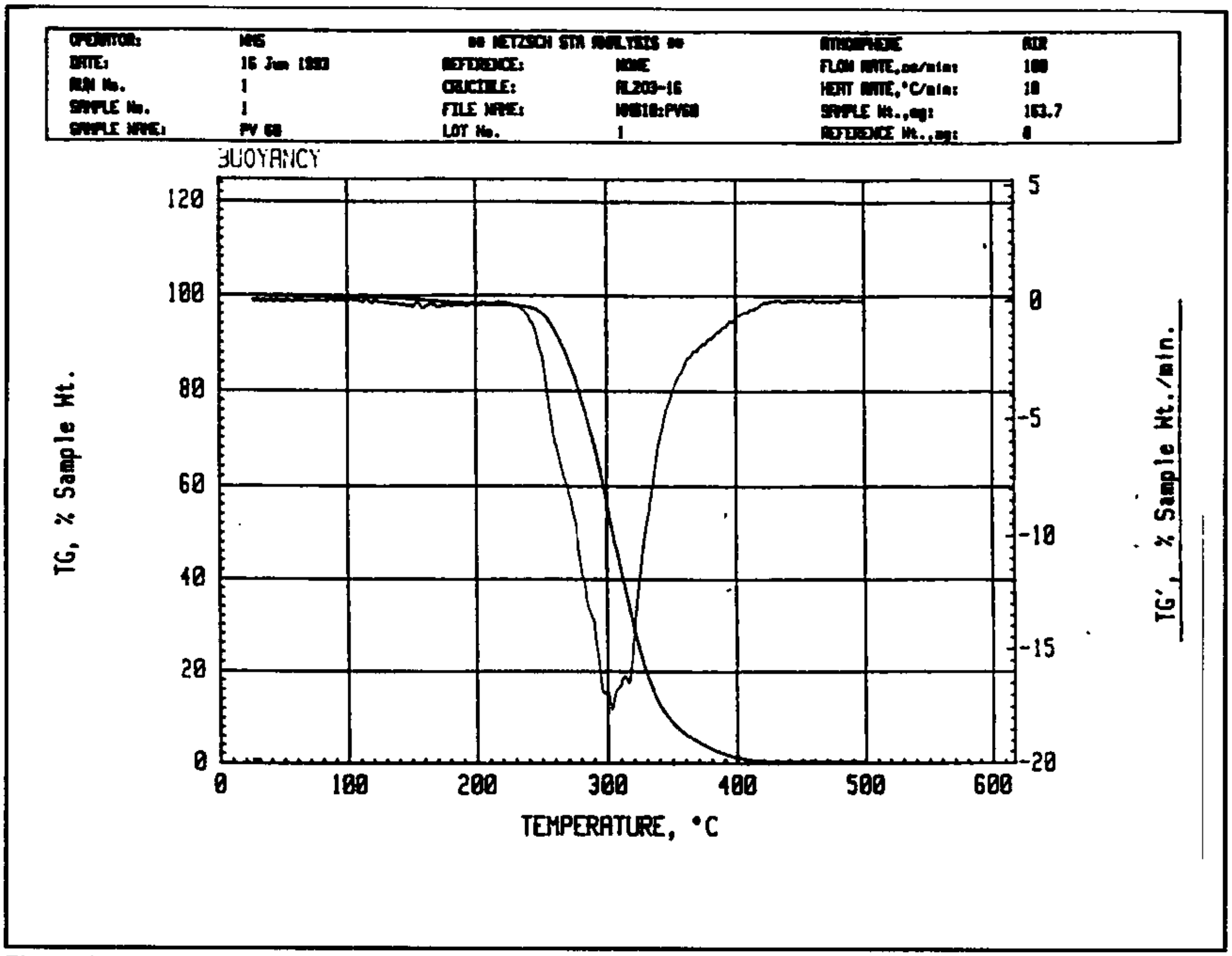
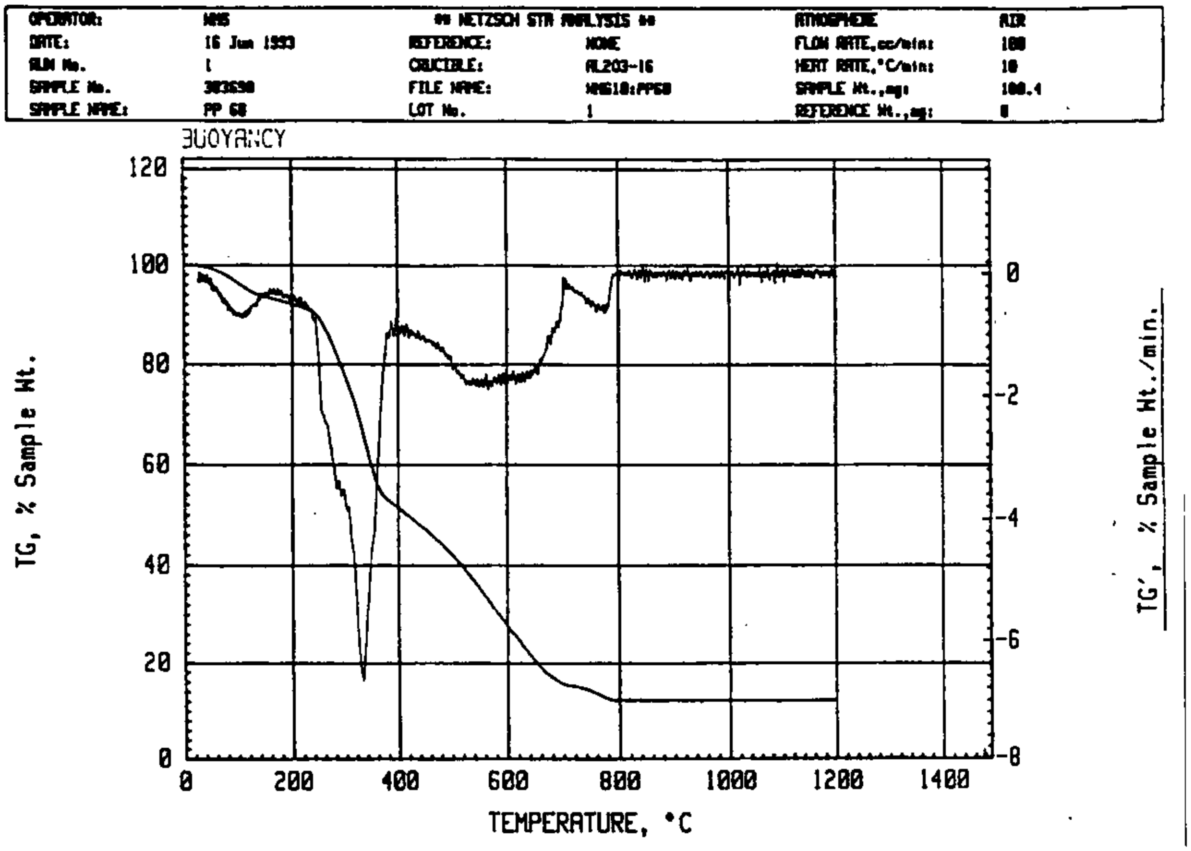
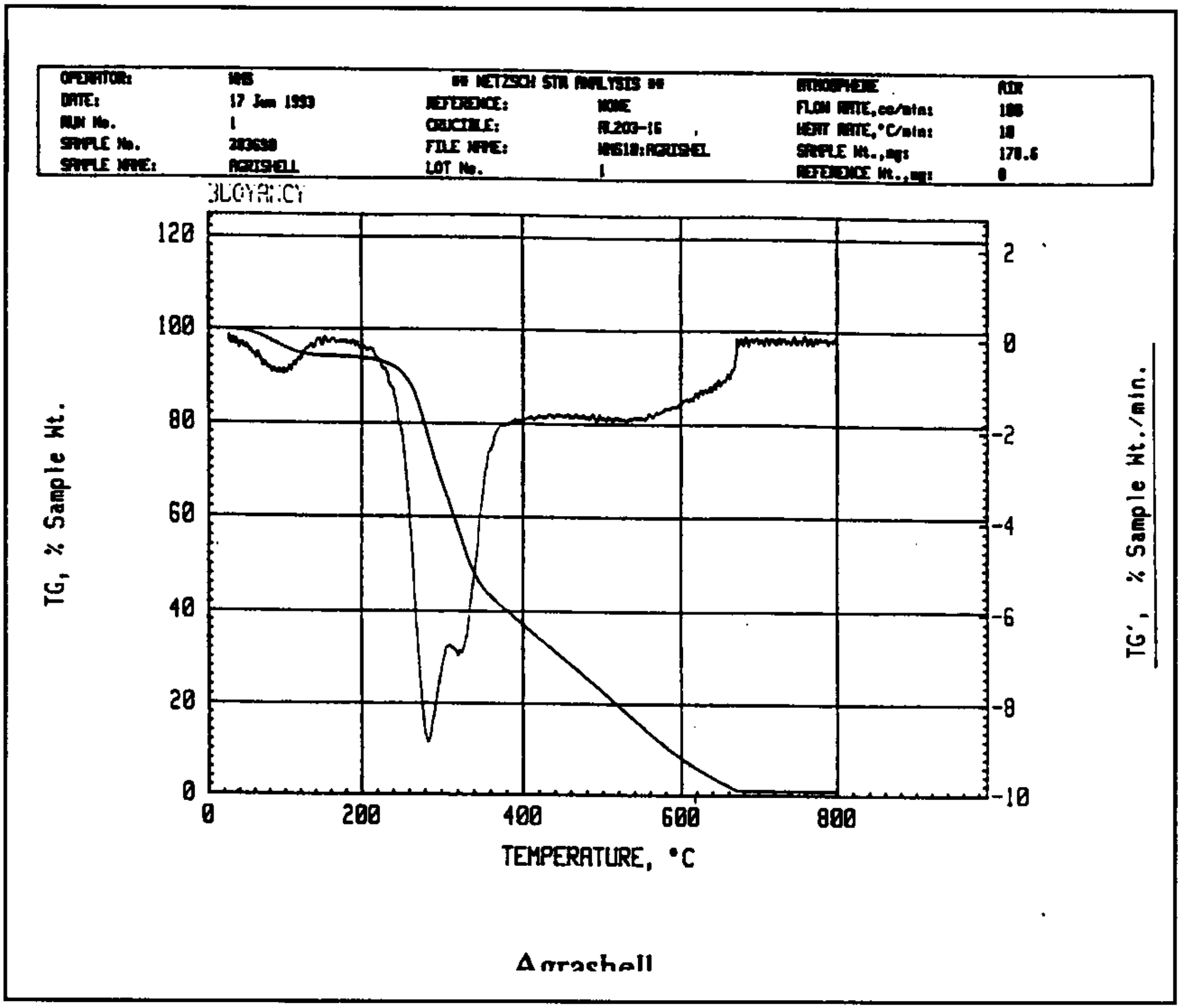


Figure 1. Mass loss for acrylic blast media during LTA for media sample PV60.



OPERATOR:	NMS	** NETZSCH STA ANALYSIS **		ATMOSPHERE	AIR
DATE:	16 Jun 1993	REFERENCE:	NONE	FLOW RATE,cc/min:	100
RUN No.	1	CRUCIBLE:	AL203-16	HEAT RATE,°C/min:	10
SAMPLE No.	303690	FILE NAME:	NMS10:PP60	SAMPLE Wt.,mg:	100.4
SAMPLE NAME:	PP 60	LOT No.	1	REFERENCE Wt.,mg:	0

Figure 2. Mass loss for urea formaldehyde blast media during LTA for media sample PP60.



		** NETZSCH STA ANALYSIS **			
OPERATOR:	NMS			ATMOSPHERE	AIR
DATE:	17 Jun 1993	REFERENCE:	NONE	FLOW RATE,cc/min:	100
RUN No.	1	CRUCIBLE:	AL203-16	HEAT RATE,°C/min:	10
SAMPLE No.	203630	FILE NAME:	NMS10:AGRISHEL	SAMPLE Wt.,mg:	170.6
SAMPLE NAME:	AGRISHELL	LOT No.	1	REFERENCE Wt.,mg:	0

Figure 3. Mass loss for ground walnut shell blast media during LTA.

Table 8. Gaseous exhaust generated during low-temperature ashing.

Paint Blast Media Sample	Ground Walnut Shells	Urea formaldehyde	Acrylic
Net Volume	0.873 L	1.899 L	1.212 L
Total Exhaust Volume	10.873 L	11.899 L	11.212 L
Net Mass	0.999 g	0.878 g	1.012 g

*Net gaseous volumes were obtained by subtracting the air affluent volume from the total gaseous volume generated during LTA experiment. Sample residues remaining after ashing were subtracted from the total sample mass to obtain the net mass.

Table 9. Volatile organic compounds collected from low-temperature ashing of ground walnut shell paint blast media.

Compound Tentatively Identified	Retention Time (min.)	Exhaust Conc. (mg/m^3)	Chamber Conc. (mg/m^3)
2-propanol	6.42-8.87	418.5	3.25
methyl acetate	9.28	95.3	0.74
propanoic acid	11.45	57.9	0.45
methyl ester of pyruvic acid	11.93	101.7	0.79
furancarboxaldehyde	12.62	158.4	1.23
butanone	13.57	88.8	0.69
acetyl-oxy-porpanone	13.68	119.8	0.93
methyl-furanone	14.08	63.1	0.49
3,4-dihydro-3H-pyran	15.03	88.8	0.69
methyl-furanone (isomer of 14.08 min peak)	15.32	200.9	1.56
phenol	16.20	90.1	0.70
dihydroxy-cyclobutene-dione	16.88	96.6	0.75
methyl-cyclopetane-dione	17.50	77.3	0.60
methyl-phenol	18.10	61.8	0.48
methoxy-phenol	18.58	202.2	0.57
mixture of oxygenated compounds	19.07	119.8	0.93
dimethoxy benzene	20.42	114.6	0.89
benzene-diol	20.70	76.0	0.59
C_2-methoxy-phenol	21.85	124.9	0.97
isomer of C_2-methoy-phenol	22.08	73.4	0.57
C_2-phenol	22.47	108.2	0.84
dimethoxy-phenol	23.03	193.1	1.5
hydroxy-methoxy-benzaldehyde	23.98	47.6	0.37
trimethoxy-benzene	24.42	100.4	0.78
methoxy-propenyl-phenol	24.52	68.24	0.53
C_2-biphenyl	25.50	52.8	0.41
C_1-fluorene	26.17	63.1	0.49
mixture of oxygenerated compounds and isomers	26.48-26.75	226.6	1.76
dimethoxy-hydroxy-benzaldehyde	27.93	117.2	0.91
dimethoxy-propenyl-phenol	28.37	85.0	0.66
phenyl-acetopohenone	29.23	48.9	0.38
dimethoxy-propenyl-benzene	29.48	54.1	0.42
trihydroxy-methylphenyl-butanone	29.85	67.0	0.52
hexadecanoic acid	35.05	115.9	0.90
hydroxy-dimethoxy-phenyl-propenal	35.52	96.6	0.75

Table 10. Volatile organic compounds collected from low-temperature ashing of acrylic paint blast media.

Compound Tentatively Identified	Retention Time (min.)	Exhaust Conc. (mg/m^3)	Chamber Conc. (mg/m^3)
carbon dioxide	2.53	191.1	1.53
water	3.50-5.58	144.8	1.16
methyl ester of methasrcyllic acid	9.32-10.44	576.9	4.62
methyl ester of pentenoic acid	12.15	31.2	0.25
hexamethyl-cyclotrisiloxane	12.42	36.2	0.29
C_9-alkanol	13.38	121.1	0.397
isomer of 12.15 min peak	13.70	25.0	0.20
alkanol	14.33	201.0	1.61
methyl ester of alkanoic acid	15.35	72.4	0.58
methyl ester of methyl-cyclohexyl carboxylic acid	16.35	38.7	0.31
C_4-dioxane	17.77	30.0	0.24
methoxy-pentenyl acetate	18.38	68.7	0.55
C_4-cyclopentane-dione	20.53	28.7	0.23
propyl ester of cyclopentenyl acetic acid	21.35	18.7	0.15
propyl ester of methacrylic acid	22.18	38.7	0.31
alkyl-ester of methacrylic acid	22.47	35.0	0.28
C_6-cyclopentene	22.60	33.7	0.27
methyl ester of phenoxy-acetic acid	23.12	37.5	0.30
isomer of above	23.42	32.5	0.26
phthalate	72.57	196.0	1.57

Table 11. Volatile organic compounds collected from low-temperature ashing urea formaldehyde paint blast media.

Compound Tentatively Identified	Retention Time (min.)	Exhaust Conc. (mg/m^3)	Chamber Conc. (mg/m^3)
carbon dioxide	2.10	58.8	0.50
water	2.77-4.98	62.4	0.53
mixture of propanol and others	7.83	34.1	0.29
dimethyl-amino-actonitrile	10.18	27.1	0.23
toluene	10.75	7.1	0.06
N-methyl-formamide	11.87	41.2	0.35
furancaboxaldehyde	12.63	5.9	0.05
1H-imidazole-2-methanol	13.45	30.6	0.26
furanone	14.90	21.2	0.18
oxygenated compounds (possible alkanol)	21.2	27.1	0.23
napthalene	23.67	40.0	0.34
alkanoic acid	26.60	10.6	0.09
n-tetradecanenitrile	31.93	12.9	0.11
methyl ester of alkanoic acid	32.28	9.4	0.08
n-hexadecanenitrile	38.37	24.7	0.21
methyl ester of alkanoic acid	38.77	20.0	0.17
n-alkylamide	41.92	42.4	0.36
n-alkylamide	55.18	36.5	0.31

5 Chemical Separation

Objective of the Technology

Treatment of contaminated abrasive blasting wastes by chemical separation (acid extraction and digestion) was investigated. Conceptually a multistage process was envisioned involving acid extraction of metal contaminants and subsequent alkaline precipitation of metal salts. The decontaminated media would be landfilled while the precipitated metals would require disposal as a hazardous waste. The purpose of this work was to develop an acid digestion process that would be suitable for all types of blast media waste.

Acid Extraction and Digestion Processes

A series of laboratory experiments was performed at USACERL to determine the feasibility of the process. Samples of contaminated blast media waste were collected from Army maintenance facilities and subjected to various digestion processes using citric acid, ethylenediaminetetraacetic acid (EDTA), nitric acid, sulfuric acid, or hydrochloric acid. Leachable metal concentrations of the principal contaminants—Pb, Cd, and Cr—were measured using TCLP before and after acid digestion.

The experimental series was dynamic in that the experimental results from one series of extraction experiments gave insights that led to the design of subsequent experiments. The initial series of extractions used 5 percent, 10 percent, and 20 percent concentrated sulfuric acid for 24 hours. In an attempt to raise the pH value of the waste solution following the extraction, a series of 7 to 12 rinses with water followed an extraction using 5 percent sulfuric acid for 24 hours. A more aggressive rinse using a NaOH/H_2O solution was also evaluated. Other acids, such as citric acid, EDTA, and nitric acid, were evaluated for use as the extraction solution. EDTA in combination with HCl was also tested. These acids were subsequently rejected, and a new series of extraction using 5 percent hydrochloric acid for 24 hours, and 5 percent nitric acid for 24 hours were performed. Subsequent work settled on the use of nitric acid as the extraction solution. The effect of nitric acid concentration was further evaluated.

To monitor the performance of the analytical procedures used, quality-control matrix spikes are called for in the TCLP protocol. The matrix spikes were added at a concentration equivalent to the corresponding regulatory level. The results of these quality-control tests are shown in Appendix C.

Results of Chemical Separation Experiments

The initial series of extractions used 5 percent, 10 percent, and 20 percent concentrated sulfuric acid for 24 hours on coal slag, mixed plastic, and glass bead blast media (Table 12). TCLP results showed a decrease in the leachable cadmium and an increase in the leachable Pb and Cr. Pb and Cr are amphoteric, with increasing solubility at high and low pH. At the low pH of the concentrated sulfuric acid extraction solution, Pb and Cr solubilities are very high.

In an attempt to raise the pH of the waste solution following extraction, an extraction solution using 5 percent H_2SO_4 for 24 hours was followed by a single rinse, either with distilled water or NaOH solution. The water rinses raised the final pH to 4.0 while the NaOH rinse raised the final pH to between 7.3 and 7.7. TCLP results showed that the leachable Cd and Cr decreased, and the Pb increased, compared to the received waste (Table 13). The increase in the TCLP results was higher for samples rinsed with NaOH solution compared to the distilled water.

A 5 percent sulfuric acid extraction for 24 hours, followed by a series of multiple rinses using a NaOH/H_2O solution, was subsequently evaluated. A water rinse followed by centrifuge and decanting of the rinse solution was repeated between 7 and 13 times, yielding final pH of between 4.3 and 5.0. The TCLP results showed that the leachable Cd and Cr decreased and that the leachable Pb increased (Table 14).

Alternative acids were then considered for use as extraction solutions. A 0.002M* citric acid extraction for 24 hours, followed by three water rinses, was performed on coal slag and glass bead blast media wastes. The rinse solutions were retained and the metal concentration determined (Table 15). The metal content decreased in successive rinse solutions. The TCLP results for the washed and rinsed blast media wastes showed the Cd and Cr to have deceased but there was no change in the TCLP results for Pb.

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* M: molar concentration.

Other acids, such as EDTA, hydrochloride, and nitric acid, were evaluated for use as extraction solutions. The use of EDTA in combination with hydrochloric acid was also evaluated (Tables 16 and 17). The HCl extraction produced TCLP results showing the leachable Cr to increase from the mixed plastic and glass waste, and for the leachable Pb to increase from the coal slag blast media waste.

An acid extraction using 100 ml 0.1M EDTA plus 2 ml HCl for 24 hours caused the Cd and Cr TCLP results to decrease, and the Pb TCLP results to increase. When either 0.1 M EDTA or 5 percent nitric acid were used by themselves as the extraction fluid for 24 hours, the TCLP results for Cd, Cr, and Pb decreased (Tables 16 and 17). However, due to the higher cost of EDTA compared to nitric acid, subsequent work focused on nitric acid as the extraction fluid.

The effect of nitric acid concentration was evaluated. Extractions using 1 percent, 3 percent, and 5 percent solutions on coal slag, mixed glass, and plastic blast media wastes were conducted. The extractions resulted in a decrease in the leachable Cd, Cr, and Pb as determined by using TCLP. No appreciable difference was detected between the 3 percent and 5 percent nitric acid extraction solutions (Table 18).

The effect of acid concentration on the TCLP results for Pb was specifically evaluated using nitric acid extraction solutions in concentrations of 0.5 percent, 1 percent, and 2 percent. The filtrates were retained and the metal contents determined (Table 19). The TCLP results for Pb decreased for all three concentration levels. The Pb content of the retained filtrate was 262 ppm in the 2 percent extraction solution, and 0.97 ppm in the 0.5 percent extraction solution.

To verify the effectiveness of nitric acid extraction on various waste streams, glass beads and plastic blast media wastes were also tested (Tables 20–21). The TCLP results for Cd, Cr, decreased while the TCLP Pb results for the plastic media showed a slight increase. Again, the more concentrated extraction fluids resulted in higher metal contents in the retained filtrates.

Various acid digestion processes using citric acid, EDTA, nitric acid, sulfuric acid, or hydrochloric acid were evaluated. A 16-hour extraction using 2.0 percent nitric acid followed by multiple rinses with deionized (DI) water was determined to be the best extraction process.

Discussion

Acid treatments were found to decrease leachable heavy metal concentrations as measured by TCLP. However, post-treatment total metals concentrations were still quite high. Table 22 shows metal concentrations of the extraction fluid following a nitric acid extraction and following a different extraction using a $LiBO_2$ (lithium metaborate) flux at 1000 °C for 5 minutes. The nitric acid extractions were found to remove only 0.1 percent of the total chromium and 0.2 percent of total barium, compared to the $LiBO_2$ flux. Thus although the leachable component of metal decreased by acid extraction, the largest portion of hazardous metal contaminants was not removed by acid digestion. The acid digestion processes removed only a fraction of the total heavy metal contaminants. Use of these processes is not recommended.

Table 12. TCLP results for sulfuric acid extraction.

Sample	Lab ID	Extraction	Conc.	Time (days)	Cd (ppm)	Cr (ppm)	Pb (ppm)
Coal Slag ANAD	800863	As Received			BDL	0.4	BDL
	800863	H_2SO_4	5%	1	BDL	BDL	12
	800863	H_2SO_4	10%	1	BDL	0.1	15
	800863	H_2SO_4	15%	1	BDL	0.1	20
	800863	H_2SO_4	5%	2	0.1	BDL	7
	800863	H_2SO_4	10%	2	BDL	0.1	7
	800863	H_2SO_4	15%	2	BDL	BDL	8
Mixed Plastic Media SAAD	800864	As Received			5.2	N/A	BDL
	800864	H_2SO_4	5%	1	1.8	51.8	15
	800864	H_2SO_4	10%	1	0.9	35.3	13
	800864	H_2SO_4	15%	1	1.7	58.8	2
	800864	H_2SO_4	5%	2	0.1	0.3	11
	800864	H_2SO_4	10%	2	0.2	0.3	11
	800864	H_2SO_4	15%	2	0.2	0.5	11
Glass Beads - CCAD	800958	As Received			31.6	2.3	0.7
	800958	H_2SO_4	5'	1	BDL	BDL	BDL
	800958	H_2SO_4	10%	1	BDL	BDL	BDL
	800958	H_2SO_4	15%	1	BDL	BDL	BDL
	800958	H_2SO_4	5%	2	0.1	BDL	0.7
	800958	H_2SO_4	10%	2	BDL	BDL	BDL
	800958	H_2SO_4	15%	2	BDL	BDL	BDL
Quality Control							
Glass Beads	800958			1	0.02	0.01	0.1
	+ 10 ppm Cd, Cr, Pb			1	9.4	11.5	7.6
	% Recovery				94	115	75
	800958			2	0.04	0	0.24
	+ 10 ppm Cd, Cr, Pb				0.91	0.11	8.42
	% Recovery			2	109	101	82

Table 13. TCLP results for sulfuric acid extraction followed by NaOH rinse.

Sample	ID	Test	Extraction	Conc	Time (hours)	Rinse	pH Final	Cd (ppm)	Cr (ppm)	Pb (ppm)
As Received	800863	Total Metals	(Lab A)					386	259	40.7
As Received	800863	TCLP	(Lab B)					0.628	0.947	4.96
Coal Slag	800863	TCLP	H_2SO_4	5%	24	NaOH	7.7	BDL	BDL	11.0
	800863	TCLP	H_2SO_4	5%	24	NaOH	7.3	BDL	BDL	10.3
As Received	800958	Total Metals	(Lab A)					472	91.4	13.6
As Received	800958	TCLP	(Lab B)					31.6	2.3	0.7
Glass Beads	800958	TCLP	H_2SO_4	5%	24	Water	4.0	BDL	BDL	0.2
	800958	TCLP	H_2SO_4	5%	24	Water	4.0	BDL	BDL	0.3
Blank								BDL	BDL	BDL
Quality Control										
	800863	TCLP	(Lab B)			NaOH	7.7	0.02	0.1	11.04
	800863 +10 ppm Cd, Cr, Pb	TCLP	(Lab B)			NaOH	7.7	10.32	9.8	17.95
% Recovery								103%	97%	69.1%

Table 14. TCLP results for sulfuric acid extraction followed by multiple water rinses.

Sample	ID	Test	Extraction	Conc %	Time hours	Rinse	No of Rinses	pH Final	Cd ppm	Cr ppm	Pb ppm
As Received	800863	Total Metals	(Lab A)						386	259	40.7
As Received	800863	TCLP	(Lab A)						0.628	0.947	4.96
Coal Slag	800863	TCLP	H_2SO_4	5%	24	Water	13	5.0	0.03	0	4.3
	800863	TCLP	H_2SO_4	5%	24	Water	13	4.8	0.05	0	5.3
	800863	TCLP	H_2SO_4	5%	24	Water	7	4.4	0.05	0	6.1
	800863	TCLP	H_2SO_4	5%	24	Water	7	4.3	0.04	0	7.2
Blank									0.04	0	0.8
Quality Control											
	800863	TCLP	H_2SO_4	5%	24	Water	13	5.0	0.03	0	4.3
	800863 + 10 ppm Cd Cr Pb	TCLP	H_2SO_4	5%	24	Water	13	5.0	11.12	9.7	14.3
% Recovery									111%	97%	100%

Table 15. Citric acid extraction results.

Sample	ID	Test	Extraction	Conc	Time hours	Rinse	No of Rinses	pH Final	Cd ppm	Cr ppm	Pb ppm
As Received	800863	Total Metals	(Lab A)						386	259	40.7
As Received	800863	TCLP	(Lab A)						0.628	0.947	4.96
Coal Slag	800863	TCLP	Citric Acid	0.02M	24	Water	3		0.1	0.2	4.8
1st Rinse									0.7	4.5	34.9
2nd Rinse									0.2	0.9	8.2
3rd Rinse									0.1	0.3	2.3
As Received	800958	Total Metals							472	91.4	13.6
As Received	800958	TCLP							31.6	2.3	0.7
Glass Beads	800958	TCLP	Citric Acid	0.02M	24	Water	3		0.1	0.1	0.4
1st Rinse									24.2	3.6	1.3
2nd Rinse									3.1	0.4	0.4
3rd Rinse									0.3	0.1	0.3
Quality Control											
	800863	TCLP							0.1	0.2	4.8
	800863 + 10 ppm Cd Cr Pb	TCLP							7.7	9.9	15.3
% Recovery									76%	97%	105%

Table 16. Results for EDTA, nitric acid, and hydrochloric acid extraction from waste sample 800863.

Sample	ID	Test	Extraction Fluid	Conc	Time hours	Rinse	No of Rinses	pH Final	Cd ppm	Cr ppm	Pb ppm
As Received	800863	Total Metals	(Lab A)						386	259	40.7
As Received	800863	TCLP	(Lab B)						0.37	BDL	BDL
Coal Slag	800863	TCLP	EDTA	0.1M	24	Water	5		0.29	0.3	1
Filtrate									5.92	17.78	139
3rd Rinse									0.16	0.07	0.7
5th Rinse									0.12	0.01	0.2
As Received	800863	TCLP							0.37	BDL	BDL
Coal Slag	800863	TCLP	Nitric	5%	24	Water	5		0.05	0.01	0.1
Filtrate									7.28	87.64	355.2
3rd Rinse									0.12	0.06	0.5
5th Rinse									0.1	0.016	0.16
As Received	800863	TCLP							0.37	BDL	BDL
Coal Slag	800863	TCLP	EDTA + HCl	0.1M 2%	24	Water	5		0.46	0.04	6.3
Filtrate									5.32	75.74	205.02
3rd Rinse									0.16	0.08	0.7
5th Rinse									0.11	0.02	0.5
As Received	800863	TCLP							0.37	BDL	BDL
Coal Slag	800863	TCLP	HCl Acid	5%	24	Water	5		0.19	0.02	1.9
Filtrate									3.56	41.16	152.48
3rd Rinse									0.1	1.02	4.9
5th Rinse									0.07	0.01	0.3

Table 17. Results for EDTA, nitric acid, and hydrochloric acid extraction of waste sample 800963.

Sample	ID	Test	Extraction Fluid	Conc %	Time hours	Rinse	No of Rinses	pH Final	Cd ppm	Cr ppm	Pb ppm
As Received	800963	Total Metal	(Lab A)						16.7	256	888
As Received	800963	TCLP	(Lab A)						0.783	0.65	4.41
Plastic/Glass	800963	TCLP	Water		24	Water	5		25.25	2.36	1.2
Filtrate									25.69	107.84	0.48
3rd Rinse									2.17	8.83	0.1
5th Rinse									0.9	2.16	0.1
As Received	800963	TCLP							0.783	0.65	4.41
Plastic/Glass	800963	TCLP	EDTA	0.1M	24	Water	5		0.64	1.89	0.4
Filtrate									268.21	127.12	17.31
3rd Rinse									8.08	4.2	0.7
5th Rinse									0.96	1.2	0.7
As Received	800963	TCLP							0.783	0.65	4.41
Plastic/Glass	800963	TCLP	Nitric Acid	5%	24	Water	5		1.05	0.1	0.1
Filtrate									252.17	251.35	251.35
3rd Rinse									3.68	1.29	1.29
5th Rinse									0.85	0	0.04
As Received	800963	TCLP							0.783	0.65	4.41
Plastic/Glass	800963	TCLP	HCl Acid	5%	24	Water	5		2.1	0.13	0.13
Filtrate									199.76	167.85	167.85
3rd Rinse									8.28	1.28	1.28
5th Rinse									3.25	0.04	0.04

Table 18. Nitric acid extractions from waste sample 800863.

Sample	ID	Test	Extraction Fluid	Conc %	Time hours	Rinse	No of Rinses	pH Final	Cd ppm	Cr ppm	Pb ppm
As Received	800863	Total Metal							386	259	40.7
As Received	800863	TCLP							0.628	0.947	4.96
Coal Slag	800863	TCLP	Nitric Acid	1%	24				0	0.20	0.30
	800863	TCLP	Nitric Acid	3%	24				0	0	0.03
	800863	TCLP	Nitric Acid	5%	24				0.01	0	0.03
	800863	TCLP	HCl Acid	5%	24				0	0	0.72
As Received	800963	Total Metals							16.7	256	888
As Received	800963	TCLP							0.783	0.65	4.41
Plastic/Glass	800963	TCLP	Nitric Acid	1%	24				0.01	0.50	0.06
	800963	TCLP	Nitric Acid	3%	24				0.01	0.21	0.10
	800963	TCLP	Nitric Acid	5%	24				0.02	0.14	0.16
	800963	TCLP	HCl Acid	5%	24				0.09	0.11	0.10

Table 19. Nitric acid extraction results for lead.

Sample	ID	Test	Extraction Fluid	Conc %	Time hours	Rinse	No of Rinses	pH Final	Pb ppm	Pb ppm	Average Pb ppm
As Received	800863	Total Metal	(Lab B)						727.8		727.8
As Received	800863	TCLP	(Lab B)						3.29	3.29	3.29
Coal Slag	800863	TCLP	DI Water		16	Water	3		3.38	3.38	3.29
Filtrate									0	0	0
Rinse 1									0	-0.02	-0.01
Rinse 2									0	0	0.01
Rinse 3										-0.01	-0.01
As Received	800863	TCLP							3.29	3.29	3.29
Coal Slag	800863	TCLP	Nitric Acid	0.5%	16	Water	3		1.70	1.57	1.64
Filtrate									0.96	0.98	0.97
Rinse 1									0.33	0.35	0.34
Rinse 2									0.22	0.25	0.24
Rinse 3									0.22	0.24	0.23
As Received	800863	TCLP							3.29	3.29	3.29
Coal Slag	800863	TCLP	Nitric Acid	1.0%	16	Water	3		1.44	1.42	1.43
Filtrate									86.40	N/A	86.40
Rinse 1									8.73	8.82	8.78
Rinse 2									3.81	3.88	3.85
Rinse 3									2.35	2.33	2.34
As Received	800863	TCLP							3.29	3.29	3.29
Coal Slag	800863	TCLP	Nitric Acid	2.0%	16	Water	3		1.52	1.38	1.45
Filtrate									262.50	N/A	262.50
Rinse 1									16.93	17.07	17.00
Rinse 2									8.98	9.11	9.05
Rinse 3									4.38	4.43	4.41

Table 20. Nitric acid extraction results for glass media waste sample 800961.

Sample	ID	Test	Extraction Fluid	Conc %	Time hours	Rinse	No of Rinses	pH Final	Cd ppm	Cr ppm	Pb ppm
As Received	800961	Total Metal	(Lab A)						20.7	20.7	142.1
As Received	800961	TCLP	(Lab B)						0.72	BDL	5.05
Glass Beads	800961	TCLP	DI		16	Water	3		0.05	0.96	0.26
Filtrate									0.11	0.32	0.01
Rinse 1									0.08	0.01	0
Rinse 2									0.08	0	0
Rinse 3									0.05	0	0
As Received	800961	TCLP									
Glass Beads	800961	TCLP	Nitric Acid	0.5%	16	Water	3		0	0.01	0.01
Filtrate									13.58	0.61	77.38
Rinse 1									1.5	0.21	8.12
Rinse 2									0.15	0.14	0.89
Rinse 3									0	0.06	0
As Received	800961	TCLP									
Glass Beads	800961	TCLP	Nitric Acid	2.0%	16	Water	3		0	0	0.01
Filtrate									13.50	0.92	69.34
Rinse 1									1.56	0.23	7.65
Rinse 2									0.18	0.06	0.91
Rinse 3									0	0.05	0
As Received	800961	TCLP									
Glass Beads	800961	TCLP	Nitric Acid	5.0	16	Water	3		0	0.03	0.01
Filtrate									15.74	1.07	71.70
Rinse 1									1.75	0.25	7.82
Rinse 2									0.21	0.09	1.00
Rinse 3									0.02	0.08	0.01

Table 21. Nitric acid extraction results for PMB waste.

Sample	ID	Test	Extraction Fluid	Conc %	Time Hours	Rinse	No of Rinses	pH Final	Cd ppm	Cr ppm	Pb ppm
As Received	800968	Total Metal	(Lab B)						39.4	704	675.2
As Received	800968	TCLP	(Lab B)						1.5	11.0	BDL
Plastic Beads	800968	TCLP	DI		16	Water	3		1.32	4.59	0.44
Filtrate									0.64	65.64	0.05
Rinse 1									0.20	21.17	0.04
Rinse 2									0.13	13.29	0.03
Rinse 3									0.10	9.40	0
As Received	800968	TCLP									
Plastic Beads	800968	TCLP	Nitric Acid	0.5%	16	Water	3		0.01	0.23	1.19
Filtrate									22.56	141.75	13.5
Rinse 1									5.25	35.28	3.32
Rinse 2									1.2	8.22	1.23
Rinse 3									0.34	2.66	0.67
As Received	800968	TCLP									
Plastic Beads	800968	TCLP	Nitric Acid	2.0%	16	Water	3		0.00	0.16	0.18
Filtrate									23.06	425.75	164.00
Rinse 1									5.43	31.00	48.29
Rinse 2									1.31	23.41	12.50
Rinse 3									0.37	7.23	3.95
As Received	800968	TCLP									
Plastic Beads	800968	TCLP	Nitric Acid	5.0	16	Water	3		0.00	0.20	0.70
Filtrate									20.86	482.50	220.00
Rinse 1									4.70	94.00	51.81
Rinse 2									1.09	23.85	3.60
Rinse 3									0.28	8.62	5.15

Table 22. Comparison of nitric acid and $LiBO_2$ flux digestion for metals analysis.

Test No.	Sample	Test	Cd ppm	Pb ppm	Cr ppm	Ba ppm
124	P1	HNO_3	1.79	34.01	22.99	30.22
125	P1	HNO_3	1.65	33.08	22.58	30.51
159	P1	$LiBO_2$			20557	3044
160	P1	$LiBO_2$			17199	2580
133	P2	HNO_3	1.57	30.14	20.88	28.02
134	P2	HNO_3	1.46	28.04	19.95	27.16
161	P2	$LiBO_2$			18470	2780
162	P2	$LiBO_2$			18955	2672
128	P3	HNO_3	0.41	5.53	6.92	4.36
129	P3	HNO_3	0.38	5.86	6.91	4.54
163	P3	$LiBO_2$			9219	478
164	P3	$LiBO_2$			9165	455
135	P4	HNO_3	0.35	5.39	5.47	4.98
136	P4	HNO_3	0.39	5.55	5.76	5.13
157	P4	HNO_3 - $LiBO_2$			6842	518
158	P4	HNO_3 - $LiBO_2$			6865	508
138	Glass 5	HNO_3	4.69	1.38	0.10	0.03
139	Glass 5	HNO_3	4.44	1.20	0.10	0.03
150	Glass 5	$LiBO_2$			4	9
151	Glass 5	$LiBO_2$			13	11
142	Glass 6	HNO_3	0.52	0.39	0.21	0.14
143	Glass 6	HNO_3	0.39	0.26	0.13	0.09
155	Glass 6	$LiBO_2$			45	25
156	Glass 6	$LiBO_2$			35	12
145	Sand 7	HNO_3	0.15	0.75	0.60	1.22
146	Sand 7	HNO_3	0.15	0.79	0.58	1.15
152	Sand 7	$LiBO_2$			810	887
153	Sand 7	$LiBO_2$			819	899
165	Sand 7	HNO_3	14.5	85	70	121
166	Sand 7	HNO_3	15.5	69	60.35	126
167	Sand 7	$LiBO_2$ (after 165#)			689.5	818
168	Sand 7	$LiBO_2$ (after 165#)			726.5	804
114	Sand 8	HNO_3	0.93	0.21	0.19	0.27
115	Sand 8	HNO_3	0.94	0.15	0.19	0.21
30	Sand 8	$LiBO_2$	86		40	704
31	Sand 8	$LiBO_2$	82		38	765

6 Biodegration Through Microbial Digestion

Objective

The term *biodegradation* is often used to describe a variety of quite different microbial processes that occur in natural ecosystems. Biodegradation can be defined as the breakdown of organic compounds in nature by actions of microorganism, such as bacteria, actinomycetes, and fungi. The microorganisms derive energy and may increase in biomass from the process (Riser-Roberts 1992). The breakdown can proceed via either an aerobic or anaerobic digestion process. The difference is that aerobic digestion requires the presence of oxygen, while anaerobic digestion proceeds without oxygen.

The objective was to evaluate the potential of a biodegradation process to either render the contaminated paint blast media waste nonhazardous or to decrease the disposal volume. Bioremediation treatment processes that consist of the biodegradation of organic-based plastic media waste or agricultural-based blast media waste were considered in this study. Bioremediation processes would not be suitable for inorganic blast media such as mineral, slag, or glass abrasives.

Approach

DOT Technologies of Vancouver, BC, has developed a bioremediation process for the successful treatment of solvent-based paint strippers. The process was modified to treat starch-based ground walnut shell blast media wastes generated by the commercial airline industry (Oestreich and Waugh 1993; Oestreich and Waugh 1994). A preliminary evaluation of this process was conducted by USACERL.

The DOT bioremediation process starts with a starch enzyme liquefaction step. To make the starch blast media soluble in water, the starch waste must be dispersed in water and treated with an enzyme. The alpha amylase enzyme is widely used in the starch industry to liquefy starch for the production of syrups and sweeteners. The enzyme particle is specifically designed to cleave the starch polymers, reducing the carbohydrate polymers to simple sugars and low-molecular-weight oligosaccharides.

Following liquefaction, the mixture is filtered through 25- and 15-micron filters. The paint solids that accumulate in the particulate filters, can be directly disposed of as a hazardous waste or further digested. The volume of paint solids collected was typically 5 to 10 percent of the original starch waste volume. The filtered starch solution is then passed through an ion-exchange system to remove metal contaminants, including heavy metals.

The resulting starch solution is transferred to starch waste digestion. A bacteria and nutrient package is added to start the digestion and the starch is degraded over a 5-7 day period. Specific-gravity readings can be used to monitor the solids reduction with time to indicate when the starch has been fully digested. The remaining water is pumped back to disperse the next batch of starch waste, and the process is repeated.

Discussion

The disposal costs for the bioremediation of starch waste were projected by DOT Technologies to compare favorably to current methods of disposal in a hazardous waste landfill. Total cost per pound[*] were estimated to range from US $0.50/lb for waste volumes greater than 150,000 lb, to $0.75 US/lb for waste volumes of less than 50,000 lb.

The advantage of the bioremediation process developed by DOT Technologies is that the process decreases the disposal volume of the hazardous waste.

Disadvantages include the following:

- The complexity of the bioremediation process impacts its feasibility for use on an industrial scale at an Army facility
- Bioremediation requires specialized knowledge and equipment not currently available at most army depot facilities
- The DOT Technologies process was developed specifically for ground walnut shell media; the process can not be modified for use with other media types
- The selection of the bacteria may be specific to the waste stream, requiring different mixtures of bacteria for different waste streams
- The final extraction of the hazardous species in the treatment process and their disposal is ambiguous and needs further clarification

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[*] 1 lb. = 0.4536 kg.

- Abrasive blasting with starch media is not a major depaint method at Army depots.

Considering these disadvantages, the use of a bioremediation process for treating paint blast media waste at Army facilities is not recommended.

7 Self-Encapsulation of Plastic Media Waste

The self-encapsulation of thermoplastic blast media waste was investigated previously by Jermyn and Wichner (1991). The concept consists of heating the thermoplastic Type V - acrylic media, such that it softens to a point that it can be molded into a non-leachable waste form. The self-encapsulation of Type V acrylic waste by softening and pressure molding was shown to pass EPA leachability requirements (Table 23). Thermoset media Types I, II, III, and IV do not melt on heating, but directly decompose. To encapsulate these waste types, they were mixed with a thermoplastic material. The thermoplastic would soften, encapsulating the contaminated thermoset blast media wastes. Table 23 shows that encapsulation with a 1:3 blend of Type II media wastes in Type V thermoplastic material failed the TCLP leachability test for Cd and Cr.

Self-encapsulation of plastic media was found to be effective only with Type V thermoplastic blast media waste. The limited data showed that self-encapsulation was not effective on thermoset media blended into thermoplastic media. Because most depot depaint operations use a variety of both thermoplastic and thermoset plastic media, a treatment process applicable only to one type of plastic medium is of limited utility to the Army.

Table 23. TCLP results for self-encapsulated plastic media waste materials.

	Ba ppm	Cd ppm	Cr ppm	Pb ppm	Status
Type V Waste	1.5	0.83	19	0.07	Passed
Self-encapsulated Type V Pellet	1.0	0.26	2.7	0.82	Passed
Type II Waste	1.5	2.0	29	0.08	Failed Cd, Cr
1:3 Blend, Type II: Type V	1.5	1.2	22	0.07	Failed Cd, Cr
Palletized blend	0.91	1.4	4.5	2.3	Failed Cd
TCLP Limit	100	1	5	5	

Source: Jermyn and Wichner 1991.

8 Waste Stabilization in Portland Cement

Background

Cement-based materials were the first ingredients used in chemical fixation and stabilization of hazardous wastes and have been the most widely used (Connors 1990). Cement stabilization was first used in the processing of nuclear wastes in the 1950s. Cement and cement-based materials for the treatment of both hazardous and radioactive wastes have since been widely studied (Topp 1982; Barth 1990; Canadian Portland Cement Association 1992).

Cement stabilization was investigated as a universal treatment for the waste generated by the full range of media types used at Army depot facilities.

Portland cement was patented in 1824 by Joseph Aspidin and is made by heating together limestone and clay at about 1500 °C. It was named after the natural stone that it resembled from the quarries of Portland, England. Portland cement is a mixture of various calcium silicates and calcium aluminate minerals, principally dicalcium silicate and tricalcium silicate with smaller amounts of tricalcium aluminate and calcium aluminoferrite. These are represented in the cement notation as C_2S , C_3S, C_3A, and C_4AF, respectively. A typical weight proportion of Portland cement is 55 percent C_3S, 25 percent C_2S, 10 percent C_3A, and 10 percent C_4AF.

The cement's reaction process begins with the introduction of water. The water reacts with the silicate mixture of the cement to ultimately form a hard, dense matrix. Although the specific reactions are complex (Lea 1970), it may be considered as a series of reactions between the solid cement components and a fluid (Barneyback and Diamond 1981). The fluid initially is the mixture water, and the solid component is the cement. Shortly after mixing, the water is converted into a complex alkali- and sulfate-bearing solution. On setting, some fluid is captured in the pores of the matrix. Further hydration takes place as the cement components continue to react with the pore solution. The hazardous waste can be either mixed with the dry cement or added to the mixture shortly after the water is mixed in.

The use of a cement system containing superplastizers, fly ash, and silica fume was reported to stabilize paint blast waste (Garner, Carrasquillo, and Fowler 1993). However, the specific chemical processes that occurred during the solidification were not discussed.

Approach

A multiphase approach was used. In Phase I, blast media waste samples were collected from Army depot facilities. These samples were tested for leachable metals, and those determined to be hazardous were solidified in commercial Portland cement. Cement stabilization was found to yield the paint blast samples nonhazardous for Cd, but the process was not able to stabilize Cr.

In Phase II, additional blast media waste samples were collected and characterized. To simulate the high pH chemical environment encountered during the hydration reaction in a cement matrix, the response of the paint blast media waste to simulated pore solutions was investigated.

In Phase III, the paint blast media wastes were encapsulated in Portland cement. The pore solution, which is the actual chemical environment that the wastes encounter during cement hydration, was expressed from cast cement and waste samples. The metal content of expressed pore solution was analyzed.

In the expectation that granulated blast furnace slag would chemically reduce the valence of the chromium from the waste during the cement hydration reaction, samples of paint blast media wastes were cast in a mixture of Portland cement and blast furnace slag during Phase IV. The complete laboratory results of the cement stabilization work are presented in Appendix C.

Phase I—Cement Stabilization

Paint blast media waste samples were obtained from Army Depot facilities. The concentration of leachable RCRA metals of the as-received wastes was determined by TCLP (Table 24). Five of the 10 wastes were found to be not hazardous and no additional testing was necessary. Cement stabilization of the five samples that failed TCLP was studied. These samples failed TCLP for Cd and/or Cr.

Water is necessary to initiate the cement hydration reaction. However, to form a workable body with adequate flow characteristics, additional water above the stoichiometric requirement is generally added. This is typically described in terms of the water-to-cement ratio, the stoichiometric value being 0.44. Typical commercial concrete uses a water-to-cement ratio of +/- 0.5. In the Phase I study, 22 percent Portland cement, and 11 percent water by weight were added to the waste. The three waste samples that initially failed TCLP only for Cd were successfully stabilized by this procedure. The remaining two wastes, which initially failed both for Cd and Cr as received, passed TCLP for Cd but failed the TCLP test for Cr after encapsulation. These results indicate that Cd-contaminated waste can be successfully stabilized in Portland cement.

The two wastes that failed the TCLP for Cr in the first stabilization—sand and plastic media from SSAD—were subjected to further evaluation. The wastes were treated by 20 percent Portland cement and 20 percent water additions. These wastes failed the TCLP test for Cr, and subsequently were treated with 33 percent addition of Portland cement and 17 percent water addition. Again the two wastes failed TCLP. These results indicated the difficulty of cement stabilization of Cr-contaminated waste in Portland cement.

Work beyond encapsulation and TCLP testing was necessary to gain insight into the chemical processes occurring during cement solidification. The use of simulated and expressed pore solutions was investigated and is discussed in the sections below.

Phase II—Simulated Pore Solution Analysis

Waste Characterization

Additional paint blast media waste samples generated at an Army maintenance facility were obtained for use in this and subsequent phases of the investigation. The wastes selected were among those more commonly generated at the facility. Samples were taken from a number of blasting stations for each type of media. The total metal (As, Ag, Cd, Hg, Pb, and Se) concentrations were determined by dissolving the sample in a concentrated solution of nitric acid (1 HNO_3 : 1 H_2O) at 80 °C for 12 hours. The Cr and Ba content was determined using a $LiBO_2$ flux at 1000 °C for 5 minutes. The results are presented in Table 25.

The leachable component of the waste as measured by TCLP using the EPA protocol is shown in Table 26. The results of TCLP analyses showed that seven of the eight wastes failed for Cd, and all plastic media wastes failed for Cr. Despite significant Pb and Ba contents in the raw waste, all wastes passed TCLP for those elements.

Approach

The TCLP is designed to simulate the leaching of a waste form in a municipal landfill along with other general refuse. However, the actual chemical environment that a hazardous species may encounter may be substantially different. Bishop (1988) reported that for cement-based systems, the high alkalinity quickly neutralizes all of the acid present in the leachant, so that the leaching occurs under highly alkaline conditions rather than acidic conditions. Therefore, for waste treated with Portland cement, the measured concentration of metals in TCLP leachate may not accurately represent the true stability of the waste specie.

The extraction and analysis of the pore solution from Portland cement has provided insight into the hydration process (Longuet, Burglen, and Zelwer 1973; Barneyback and Diamond 1981). Pore solutions recovered after set are typically found to be concentrated solutions of alkali hydroxides with modest contents of other compounds. The overall pH of the pore solution is extremely alkaline, with a pH >13; this is the chemical environment that any foreign species, introduced from the hazardous waste, would encounter during stabilization. Understanding the behavior of foreign species in this specific chemical environment should give insight into the chemical processes that occur during stabilization. Such an understanding was expected to permit the subsequent optimization of the stabilization matrix to enhance the long-term stabilization of hazardous wastes.

Due to the difficulty of extracting or expressing pore solution from cement samples, and the resulting complex chemistry of the pore solution environment, simulated pore solutions had to be used to model the response of a waste to this environment. An advantage of using simulated pore solutions is that the role of pH on the solubility of metal species in the waste is isolated.

The simulated pore solution used in this study consisted of 1.0M and 0.1M solutions of KOH + NaOH (3:1 mole ratio) corresponding to typical high- and low-alkali Portland cements. Samples of abrasive blast media waste (100g) were placed into 2 liters of model pore solution. After storage in a nitrogen environment for 1 day and 28 days respectively (these are standard mileposts for cement hydration), the samples were filtered and the metal contents determined. Concentrations of As, Ag, Ba, Cd, Cr, Pb, and Se were determined using inductively coupled plasma. The method detection limits (mg/l) are as follows: As = 0.11, Ba = 0.030, Cd = 0.017, Cr = 0.007, Pb = 0.066, Se = 0.18, and Ag = 0.016. A graphite furnace atomic absorption spectrometric method was used to determine Hg content (Keller, Peden, and Rattonetti 1984).

Results

The results of simulated pore solutions for each waste are presented in Table 27. The controlling factor in the response of a waste species to the simulated pore solution is the pH. Due to the high pH of cements, the pH is not directly measured. Instead, the buffering capacity to an acid titration is determined. The predominant anion is assumed to be OH^- such that the approximate pH can be calculated. The type of blast media did not seem to have significant effect on the behavior of the metal species in the waste. The length of residence in the simulated pore solution did not greatly affect the concentration of metals in solution.

All blast media wastes failed the TCLP for Cd, but when samples of the waste were exposed to the simulated pore solutions, the concentration of Cd decreased to below 1 ppm. This is consistent with the work of other investigators as summarized by Connor (1990), who reported that Cd was found to be insoluble at the high pH encountered in the model pore solution. Cd begins to leach significantly only below pH 9.

Cr exhibits amphoteric (both acid and basic) behavior with high solubility at both low and high pH (Pourbaix 1974). The plastic blast media wastes failed TCLP due to significant Cr content. When subjected to the chemical environment of the simulated pore solution, the concentration of Cr increased due to the high pH of the solution, and was dependent on the pH (Figure 4). The chromium ion is expected to be present as Cr^{6+}, which is highly soluble (Pourbaix 1974).

Similar behavior was encountered for Pb-containing wastes. Even though the samples successfully passed TCLP, when subjected to the model pore solutions the concentration of Pb increased with increasing solution pH (Figure 5). This was due to the amphoteric behavior of the Pb. For the highly alkaline conditions of the pore solution, the increased solubility of both Pb and Cr confirmed the controlling role that pH plays in the response of waste species in cement-based matrix. This demonstrates the care which must be taken in interpreting TCLP results for hazardous waste treated in cement.

Next the paint blast media wastes were encapsulated in Portland cement. The actual pore solution was extracted from cast samples of cement and blast media waste to determine directly the chemical response of the hazardous components of the waste to the actual cement hydration environment.

Phase III—Portland Cement Stabilization

Approach

In this phase, the paint blast media wastes analyzed in Phase II were encapsulated in Portland cement. An important goal in stabilization and solidification of any hazardous waste is the final disposal volume generated. In order to minimize the final disposal volume, a loading of 75 percent waste and 25 percent cement (by volume) was utilized. High waste loading also minimizes the raw material costs of the Portland cement used for stabilization.

The exact chemical and mineral makeup of Portland cement depends on the original raw materials utilized. These raw materials tend to vary depending on the local geology of origin, particularly in terms of alkali content. Therefore, in this phase, two commercially available Portland cements were used—one corresponding to the lower limit of alkali content in commercial cements and the other corresponding to the upper limit. Chemical analysis of the high- and low-alkali cements were performed using x-ray fluorescence, and are shown in Table 28.

Paint blast media waste, cement, and water were blended in a planetary mixer, cast with vibration into plastic cylinders approximately 47 x 70 mm, and sealed. Water is necessary to initiate the cement hydration reaction. However, to form a workable body with adequate flow characteristics, additional water above the stoichiometric value is generally added. In this study, water judged to yield suitable workability was added and varied depending on the fineness of the waste media. The water-to-cement ratios are presented in Tables 29 and 30. Samples were allowed to hydrate for 1 day and 28 days (for high- and low-alkali cements, respectively) before pore solutions were expressed.

A schematic of the pore expression apparatus is shown in Figure 6. Compressive loads as high as 500 MegaPascals (MPa) were applied to effectively express pore solutions from the solidified waste specimens. The expressed pore solution was collected and stored under nitrogen atmosphere until analyzed.

Results

The chemical analysis of expressed pore solutions from spent paint blast media wastes incorporated into ordinary Portland cement matrix are given in Tables 29 and 30. The OH-concentration of the pore solution expressed from cement waste forms are lower than those used in the simulated pore solution study—particularly for the plastic media P1 and P2. The high water-to-solid ratio of the waste forms, required due to the extreme fineness of the spent plastic media, diluted the alkali levels of the pore solutions. Still, the solubility of the hazardous elements in the expressed pore solutions followed the general trends seen in Phase II. The expressed pore solution contained very low concentrations of Cd and Ba (as BaSO4) in solution because Cd and Ba are insoluble at high pH.

Both Cr and Pb showed significant solubility within the matrix of the solidified waste form. The initial concentration of Cr in the expressed pore solution was much higher after 1 day hydration in both low- and high-alkali cement systems than was seen in the simulated pore solutions. In the expressed pore solutions, Cr increased in concentration with an increase in OH^- concentration (Figure 7). However, as shown in Figure 8, samples hydrated 28 days had higher $[OH^-]$ and lower Cr concentrations compared to samples hydrated 1 day. For longer times, the $[OH^-]$ concentration increased with hydration time and the Cr concentration decreased. This is opposite to the response expected with $[OH^-]$ control of the chromium concentration. It seems obvious that additional processes must be occurring. Processes to decrease the chromium concentration in the pore solution may include a very extended reduction process of the chromium or some combination of physical adsorption and/or incorporation of the Cr into the cement hydration products. It appears that the kinetics are sufficiently slow that the process may extend beyond the 28-day hydration period studied.

The concentration of Pb was not controlled by the $[OH^-]$ of the expressed pore solution (Figure 9). The Pb concentration of samples P1 and P2 decreased despite an increase in the $[OH^-]$ of the expressed pore solution. Clearly other factors besides the $[OH^-]$ influenced the solubility of Pb within the actual matrix of ordinary Portland cement waste forms. The lower Pb concentration in the expressed pore solution of the high- alkali cement may possibly be due to the higher sulfate content of the high-alkali cement (Table 28). During normal cement hydration sulfate ions are released into the pore solution. The presence of sulfates would be expected to react with the Pb species present and precipitate out a low-solubility Pb sulfide, resulting in a decrease of the Pb concentration in the pore solution.

TCLP calls for any initial liquid phase present in the waste to be added to the liquid extract, and for these to be analyzed together. The results of the TCLP analysis performed on the solid residue retained after expression of the pore solution are given in Table 31. Due to the trapping of pore solution in the many isolated submicron pores, the expression of pore solution typically only extracts 10 to 25 percent of the total pore solution. The results of TCLP performed on similar samples that did not have the pore solution expressed are shown in Table 32. No significant difference was found in the two sets of TCLP results. The Cr concentration was slightly higher in the low-alkali cement waste forms compared to the high-alkali cement wastes. TCLP analysis showed no apparent trend due to hydration time.

The plastic media waste samples P1 and P2 stabilized in Portland cement failed TCLP for Cr. The high pH of the cement completely neutralized the acid present in the TCLP test. Both the initial pH and final [OH^-] of the TCLP test were measured. For samples P1 and P2, the calculated final pH was >12.2, at which Cr is highly soluble. The Cr metal concentration of samples G5, G6, S7, and S8, which were at least one order of magnitude lower than P1 and P2 (Table 25) all passed TCLP when stabilized in Portland cement.

The final [OH^-] of the TCLP extraction fluid was in the identical range as the [OH^-] of the expressed pore solution. The similarity of the [$OH]^-$ is demonstrated clearly in Figure 10, where the chromium concentration of the expressed pore solutions is plotted on the same graph as the Cr concentration obtained from the TCLP analyses. Both the expressed pore solution and TCLP are at the same high [OH^-] such that both show the similar high Cr solubility. It is this final pH of the TCLP extraction test, controlled by the alkalinity of the cement, that determines the leachable chromium.

Summary of Phase III Results

Paint blast media wastes were encapsulated in Portland cement. The expressed pore solutions had calculated pH greater than 12. At this pH, Cd and Ba concentrations were low and Cr and Pb concentrations were high. The response of the Cr and Pb concentrations to pH and hydration time were observed. The high pH of the cement completely neutralized the acid present in the TCLP test. Samples P1 and P2, stabilized in Portland cement, failed TCLP for Cr.

Phase IV—Stabilization in Cement and Blast Furnace Slag Addition

Approach

An approach developed by Pourbaix (1974), which is widely used by electrochemists and corrosion engineers, is to represent the stability fields of ionic species on a two-dimensional plot of the electrochemical potential versus pH. The potential-pH diagram for system chromium in water is shown in Figure 11. The stabilization and solidification of Cr^{6+} is typically a two-step process, with an initial reduction of

Cr^{6+} to Cr^{3+} by the addition of ferrous salts followed by encapsulation in cement or another type of matrix.

The stability fields for Portland cement and Portland cement with blast furnace slag were superimposed by Macphee and Glasser (1993) onto Figure 11. They showed ordinary Portland cements to have a pH > 13. The addition of blast furnace slag reduced the pH to between 11 and 13, and also reduced the electrochemical potential from oxidizing to reducing. It was inferred that this may be sufficient to reduce the Cr^{6+} in equilibrium with a Portland cement system to Cr^{3+} in a blast furnace slag/cement system. Therefore, to control the stability of the chromium in a solidification matrix, it is necessary to control the electrochemical potential and pH that determines the ionic species and its solubility.

Blast furnace slag is formed during the manufacturing of iron when limestone reacts with the silica and alumina present in the ore as impurities. Blast furnace slag is a pozzolanic material; although it will not hydrate directly with water, when combined with cement it will participate in the cement hydration reaction. The addition of blast furnace slag to Portland cement is known to slow the hydration kinetics and to increase the final compressive strength of the cement (Taylor 1990).

The addition of blast furnace slag to Portland cement was investigated to test the hypothesis that it would reduce the electrochemical potential sufficiently to also reduce the valence of the chromium from the highly soluble Cr^{6+} to the more stable Cr^{3+}.

This work concentrated on the plastic media waste samples P1, P2, P3, and P4 discussed in Phase III, as these had high concentrations of Cr and failed TCLP for Cr. Samples of paint blast media waste were blended and cast with a mixture of Portland cement and granulated blast furnace slag. The cement used in Phase III was replaced with 25% by volume of the blast furnace slag yielding a composition of 75% waste and 25% cement blended with slag. The composition of the blast furnace slag as determined by x-ray fluorescence analysis is given in Table 33. The experimental procedures were similar to those used in Phase III. Samples were cast and allowed to hydrate for 1 or 28 days, as prescribed in the previous section. The pore solutions were expressed and analyzed, and TCLP analyses were performed (see Tables 34 and 35).

Results

The chromium concentration of the expressed pore solution in relation to the $[OH^-]$ is shown in Figure 12. The different wastes, with different level of contaminants, in the different cement matrices, resulted in different initial [OH$^-$]. Despite significantly different initial [OH$^-$], the partial replacement of the cement with blast furnace slag universally resulted in a decrease in the [OH$^-$] and a corresponding decrease in the Cr concentration. For both the 1 and 28 day hydrations the response was the same; partial replacement of cement by blast furnace slag resulted in a decrease in the [OH$^-$] and a corresponding decrease in the Cr concentration.

The effect of hydration on the Cr concentration of the expressed pore solutions is shown in Figure 13. The data showed an increase in [OH$^-$], with an increase in hydration time for all samples with blast furnace slag additions. With the exception of the high-alkali data for samples P1 and P2, the data showed an decrease in the chromium concentration, consistent with the Phase III results. This finding again indicates the occurrence of an unidentified long-term process to yield a decrease in the chromium concentration over time

Samples encapsulated in a mixture of Portland cement and blast furnace slag failed TCLP for Cr (Tables 36 and 37). The addition of blast furnace slag was found to have shifted the final [OH$^-$] of the TCLP extraction fluid to a slightly lower range of values (Figure 14). However, the impact of blast furnace slag additions is a secondary effect superimposed on the much greater role played by the buffering capacity of the cement matrix on the final [OH$^-$] of the TCLP extraction fluid. The expressed pore solution results showed a decrease in the Cr concentration with the addition of blast furnace slag. TCLP results showed that although three of the four samples hydrated 1 day and all four samples hydrated 28 days showed a slight decrease in the leachable Cr due to blast furnace slag additions, they all failed TCLP for Cr.

The chemical histories of these samples were quite complex. The waste was mixed with a cement or a cement/slag matrix, allowed to hydrate for 1 or 28 days, and then granulated for TCLP testing. The initial environment of the TCLP extraction was acidic. At some point during the extraction, the buffering capacity was consumed and the pH shifted to highly alkaline conditions. The leachable Cr concentration was then determined. At each step in this process, chemical reactions occurred. Normally in the acid environment of the TCLP test, the blast furnace slag should react with Cr^{6+} and reduce it to the less-soluble Cr^{3+}. It may be possible that this occurred during the initial stages of the TCLP extraction, before the buffering capacity of the acid was consumed. The shift of the TCLP from the initial acidic conditions to highly alkaline conditions had a greater affect on the final [OH$^-$] and the leachable Cr than the addition of blast furnace slag to the waste form. The leachable chromium concentration measured by the TCLP, with or without blast furnace slag, appeared to be controlled by the final high pH of the extraction solution.

Summary of Phase IV Results

Despite the replacement of the cement with blast slag, the high pH of the cement completely neutralized the acid present in the TCLP test and all samples failed TCLP for Cr. This had a greater affect on the final [OH^-] and leachable Cr than the addition of blast furnace slag to the waste form. However, the blast furnace slag additions did slightly decrease the [OH^-] and resulted in a corresponding decrease in the Cr concentration in the expressed pore solutions of waste forms hydrated for 28 days. Although this decrease may be due to the reduction of Cr valence by the blast furnace slag, the reaction kinetics appear to be too slow to make this process applicable to Army needs.

Table 24. TCLP results for 10 waste samples for Phase I cement encapsulation study.

Depot	Waste	Stabilization (wt%)	As ppm	Hg ppm	Se ppm	Cr ppm	Cd ppm	Pb ppm	Ag ppm	Ba ppm	Results
ANAD	Coal Slag		BDL	BDL	0.089	0.0296	0.497	0.801	BDL	1.5	Pass All
ANAD	Glass Beads		0.049	BDL	0.019	0.405	0.245	0.453	BDL	0.6	Pass All
ANAD	Steel		BDL	BDL	0.146	BDL	0.121	0.082	BDL	1.5	Pass All
CCAD	Star Blast		0.024	BDL	0.026	0.144	0.084	0.171	0.1	0.1	Pass All
CCAD	Plastic		0.026	BDL	BDL	3.353	0.058	0.479	BDL	0.1	Pass All
ANAD	Mg/Fe Silicates		BDL	BDL	BDL	0.0693	10.051	0.308	0.01	1.7	Fail Cd
ANAD	Mg/Fe Silicates	22%Cem + 11% H_2O	BDL	BDL	0.017	0.028	BDL	BDL	BDL	0.2	Pass All
ANAD	Alumina		BDL	BDL	BDL	0.602	2.721	0.611	BDL	0.3	Fail Cd
ANAD	Alumina	22%Cem + 11%H_2O	BDL	BDL	0.023	0.122	BDL	0.019	BDL	0.2	Pass All
SAAD	Sand		BDL	BDL	BDL	12.9	1.5	0.1	BDL	0.7	Fail Cr, Cd
SAAD	Sand	22%Cem + 11%H_2O	BDL	BDL	0.021	6.659	BDL	BDL	BDL	0.2	Fail Cr
SAAD	Sand	22%Cem + 20%H_2O	BDL	BDL	0.029	7.518	BDL	BDL	BDL	0.2	Fail Cr
SAAD	Sand	33%Cem + 17%H_2O	BDL	BDL	0.04	4.999	BDL	BDL	BDL	0.4	Fail Cr
SAAD	Plastic		0.094	BDL	0.088	19.6	2.8	0.1	BDL	0.9	Fail Cr, Cd
SAAD	Plastic	22%Cem + 11% H_2O	BDL	BDL	0.012	13.2	BDL	BDL	BDL	0.2	Fail Cr
SAAD	Plastic	22%Cem + 20% H_2O	0.04	BDL	0.026	13.2	BDL	BDL	BDL	0.3	Fail Cr
SAAD	Plastic	33%Cem + 17% H_2O	0.04	BDL	0.025	10.259	BDL	BDL	0.046	0.3	Fail Cr
SAAD	Glass Beads		0.037	BDL	0.0256	0.379	14.8	3.5	BDL	0.3	Fail Cd
SAAD	Glass Beads	22%Cem. + 11% H_2O	BDL	BDL	BDL	0.206	BDL	BDL	BDL	0.1	Pass All
TCLP Limits			5.0	0.2	1.0	5.0	1.0	5.0	5.0	100.0	

Table 25. Total metal analysis of Army-generated paint blast media waste (ppm).

	Cd	As	Pb	Hg	Ba	Se	Ag	Cr
Plastic 1	172.0	< 11.0	3355.0	<10.0	2812.0	<18.0	<10.0	20557.0
Plastic 2	152.0	<11.0	2909.0	<10.0	2726.0	<18.0	<10.0	18173.0
Plastic 3	39.5	<11.0	570.0	<10.0	467.0	<18.0	<10.0	9192.0
Plastic 4	37.0	<11.0	547.0	<10.0	518.0	<18.0	<10.0	6842.0
Glass 1	457.0	<11.0	129.0	<10.0	10.0	<18.0	<10.0	8.5
Glass 2	45.5	<11.0	332.5	<10.0	18.5	<18.0	<10.0	40.0
Sand 1	15.0	<11.0	77.0	<10.0	893	<18.0	<10.0	815.0
Sand 2	93.5	<11.0	18.0	<10.0	735	<18.0	<10.0	39.0

Table 26. TCLP analysis of Army-generated paint blast media waste (ppm).

Waste	Cd	As	Pb	Hg	Ba	Se	Ag	Cr	Status
Plastic 1	4.90	0.14	<0.066	<0.1	0.65	<0.18	<0.016	43.07	Failed Cd, Cr
Plastic 2	5.15	0.14	<0.066	<0.1	0.74	<0.18	<0.016	44.73	Failed Cd, Cr
Plastic 3	1.35	<0.11	<0.066	<0.1	0.55	<0.18	<0.016	18.01	Failed Cd, Cr
Plastic 4	1.35	<0.11	<0.066	<0.1	0.56	<0.18	<0.016	16.32	Failed Cd, Cr
Glass 1	28.17	<0.11	4.86	<0.1	0.09	<0.18	<0.016	0.16	Failed Cd
Glass 2	1.93	<0.11	0.24	<0.1	0.17	<0.18	<0.016	0.03	Failed Cd
Sand 1	0.62	<0.11	0.18	<0.1	1.03	<0.18	<0.016	0.47	Passed
Sand 2	4.85	<0.11	0.10	<0.1	0.30	<0.18	<0.016	0.10	Failed Cd
TCLP Limit	1.00	5.00	5.00	0.20	100.00	1.00	5.00	5.00	

Table 27. Results of simulated pore solutions for each waste.

Waste	Solution	Time	[OH-] start	[OH-] end	Cd	Pb	Cr	Ba
P1	0.1M	1	0.0993	0.0790	0.02	31.70	92.54	0.05
P1	0.1M	28	0.0998	0.0687	0.029	30.68	89.06	0.03
P1	1M	1	0.993	0.963	0.17	77.29	102.7	0.27
P1	1M	28	0.998	0.945	0.09	84.98	104.5	0.28
P2	0.1M	1	0.0993	0.0818	<0.017	25.69	88.48	0.04
P2	0.1M	28	0.0998	0.0685	0.026	27.62	86.87	0.03
P2	1M	1	0.993	0.960	0.19	74.11	113.8	0.26
P2	1M	28	0.998	0.954	0.11	88.75	106.7	0.30
P3	0.1M	1	0.0993	0.0929	<0.017	8.86	23.22	0.03
P3	0.1M	28	0.0998	0.0887	<0.017	12.49	27.69	0.03
P3	1M	1	0.993	0.980	<0.017	18.01	38.14	0.25
P3	1M	28	0.998	0.980	0.03	21.93	39.95	0.37
P4	0.1M	1	0.0993	0.0935	<0.007	8.91	21.72	<0.03
P4	0.1M	28	0.0998	0.0894	<0.017	13.83	28.00	0.03
P4	1M	1	0.993	0.983	<0.017	18.41	32.00	0.24
P4	1M	28	0.998	0.979	0.04	23.96	36.72	0.39
G5	0.1M	1	0.0993	0.0968	<0.017	2.07	0.129	<0.03
G5	0.1M	28	0.0998	0.0973	<0.017	3.74	0.12	<0.03
G5	1M	1	0.993	0.989	0.31	1.42	0.053	0.05
G5	1M	28	0.989	0.976	0.28	4.71	0.067	0.06
G6	0.1M	1	0.0993	0.0983	<0.017	<0.066	0.032	<0.03
G6	0.1M	28	0.0998	0.0988	<0.017	0.10	0.038	<0.03
G6	1M	1	0.993	0.993	0.28	0.37	0.038	0.04
G6	1M	28	0.989	0.979	0.089	0.60	0.062	<0.03
S7	0.1M	1	0.0993	0.0964	<0.017	0.42	1.258	<0.03
S7	0.1M	28	0.0998	0.0957	<0.017	0.37	1.43	<0.03
S7	1M	1	0.989	0.975	0.019	2.01	1.44	0.29
S7	1M	28	0.993	0.984	<0.017	1.96	1.50	0.13
S8	0.1M	1	0.0993	0.0980	<0.017	0.12	0.144	<0.03
S8	0.1M	28	0.0998	0.0977	<0.017	0.14	0.17	<0.03
S8	1M	1	0.993	0.987	0.18	0.46	0.29	0.09
S8	1M	28	0.989	0.977	0.018	0.48	0.22	0.08

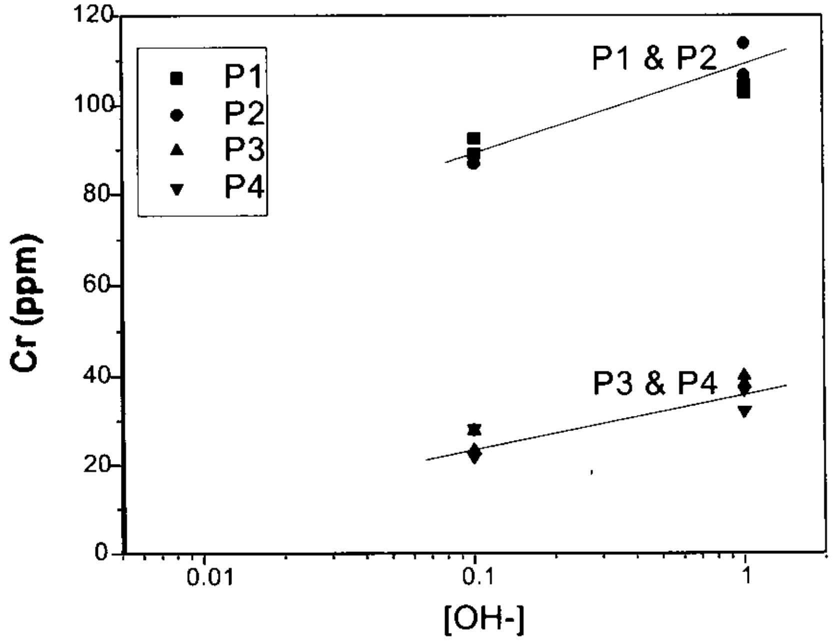


Figure 4. Dependence of chromium concentration on [OH-] of model pore solutions.

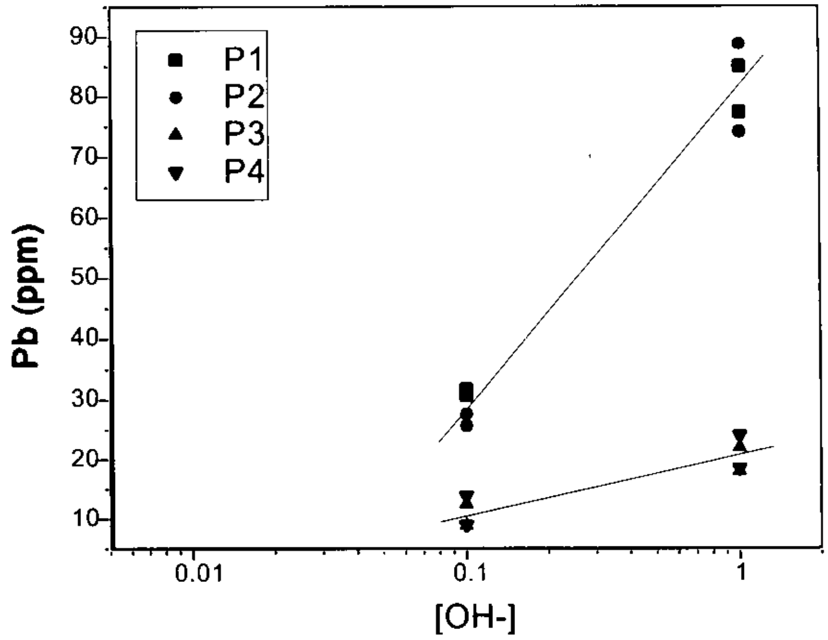


Figure 5. Dependence of lead concentration on [OH-] of model pore solutions.

Table 28. X-ray fluorescence analysis of low- and high-alkali cements.

Oxide Equivalent	Low Alkali Cement	High Alkali, Cement
SiO_2	24.04	20.45
Al_2O_3	2.58	5.41
Fe_2O_3	0.28	2.00
CaO	68.90	64.21
MgO	1.07	2.72
K_2O	0.03	1.07
Na_2O	0.14	0.24
TiO_2	0.13	0.27
P_2O_5	0.10	0.13
MnO	0.02	0.044
SO_3	2.31	2.93
Totals	99.60	99.47

Table 29. Chemical analysis of expressed pore solutions in low- and high-alkali Portland cement (1-day hydration).

Waste	Cement	Hydration days	Water/ Cement (Wt.)	[OH-] end	pH end*	Cd ppm	Pb ppm	Cr ppm	Ba ppm
P1	Low Alk.	1	1.22	0.0160	12.20	0.37	14.9	652	0.58
P1	High Alk.	1	1.21	0.0188	12.27	<0.17	7.7	1310	0.32
P2	Low Alk.	1	1.22	0.0178	12.25	0.30	16.4	612	0.83
P2	High Alk.	1	1.22	0.0200	12.30	<0.17	7.5	1330	<0.30
P3	Low Alk.	1	0.69	0.0728	12.89	<0.17	<0.66	21.5	2.85
P3	High Alk.	1	0.69	0.2390	13.37	<0.17	<0.66	155	2.14
P4	Low Alk.	1	0.69	0.0610	12.79	<0.17	<0.66	11.8	3.27
P4	High Alk.	1	0.69	0.2900	13.46	<0.17	<0.66	87.5	1.32
G5	Low Alk.	1	0.57	0.1115	13.05	<0.17	<0.66	<0.07	1.24
G5	High Alk.	1	0.56	0.5760	13.76	0.189	2.32	0.13	0.45
G6	Low Alk.	1	0.57	0.0820	12.91	<0.17	<0.66	0.07	1.34
G6	High Alk.	1	0.56	0.5212	13.70	<0.17	<0.66	0.40	0.37
S7	Low Alk.	1		0.0751	12.87	<0.17	<0.66	0.36	1.81
S7	High Alk.	1		0.2990	13.48	<0.17	0.78	1.50	1.07
S8	Low Alk.	1		0.0812	12.91	<0.17	<0.66	0.08	1.29
S8	High Alk.	1		0.3558	13.55	<0.17	<0.66	0.16	0.73

*calculated

Table 30. Chemical analysis of expressed pore solutions in low- and high-alkali Portland cement (28-day hydration).

Waste	Cement	Hydration days	Water/ Cement (Wt.)	[OH-] end	pH end*	Cd ppm	Pb ppm	Cr ppm	Ba ppm
P1	Low Alk.	28	1.22	0.0180	12.25	0.30	18.1	333	1.05
P1	High Alk.	28	1.21	0.0242	12.38	<0.17	8.46	1080	0.45
P2	Low Alk.	28	1.22	0.0196	12.29	0.29	19.0	263	1.18
P2	High Alk.	28	1.22	0.0252	12.40	<0.17	8.33	1040	0.40
P3	Low Alk.	28	0.69	0.0921	12.96	0.37	1.71	0.40	N/A
P3	High Alk.	28	0.69	0.9572	13.98	<0.17	7.57	49.5	3.16
P4	Low Alk.	28	0.69	0.0773	12.89	<0.17	<0.66	5.26	2.38
P4	High Alk.	28	0.69	0.6730	13.82	<0.17	4.25	30.61	2.71
G5	Low Alk.	28	0.57	0.2520	13.40	<0.17	<0.66	0.25	0.40
G5	High Alk.	28	0.56	0.8620	13.93	<0.17	3.15	1.02	0.46
G6	Low Alk.	28	0.57	0.1916	13.28	<0.17	<0.66	0.13	0.65
G6	High Alk.	28	0.56	0.7745	13.89	<0.17	<0.66	1.09	0.48

*calculated

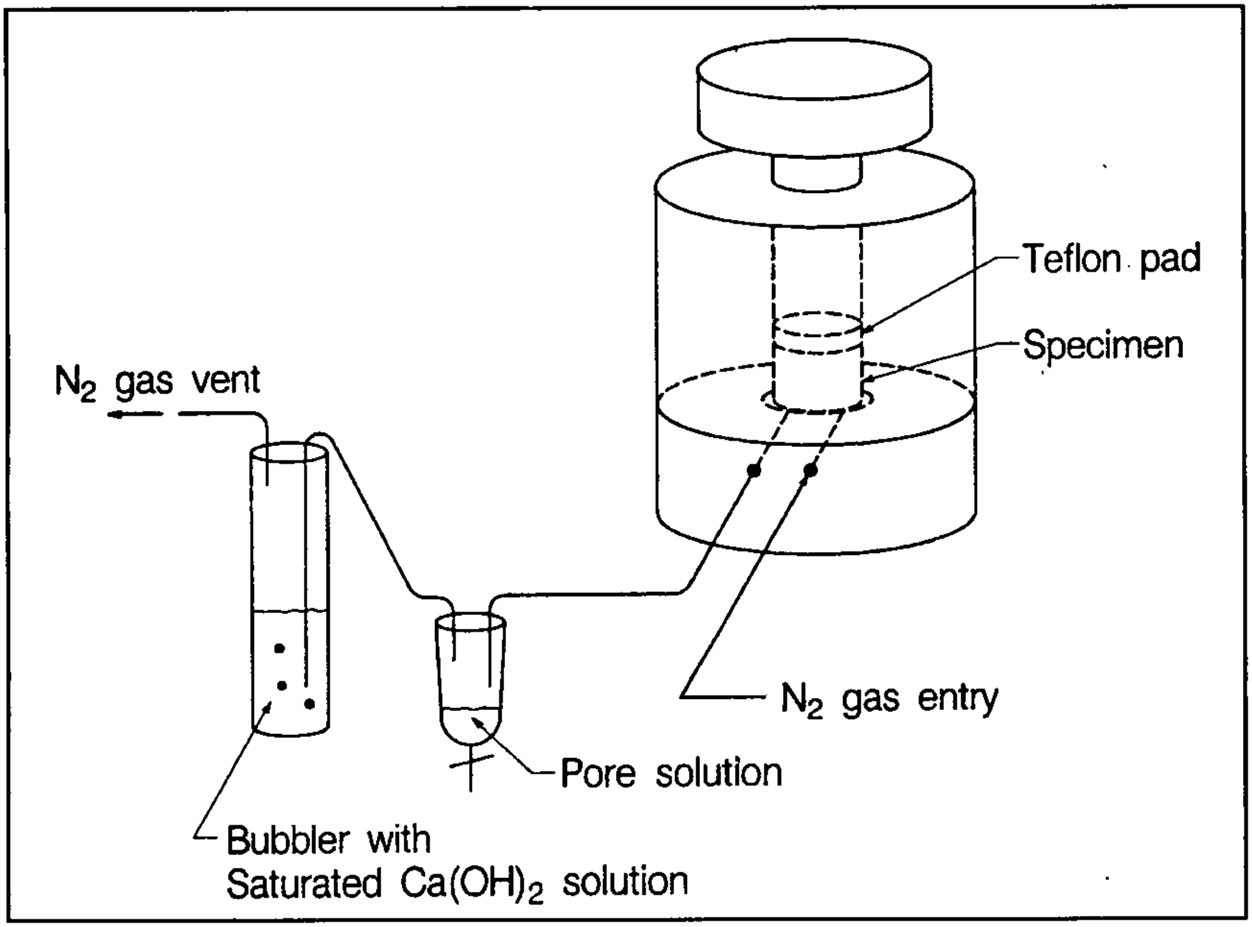
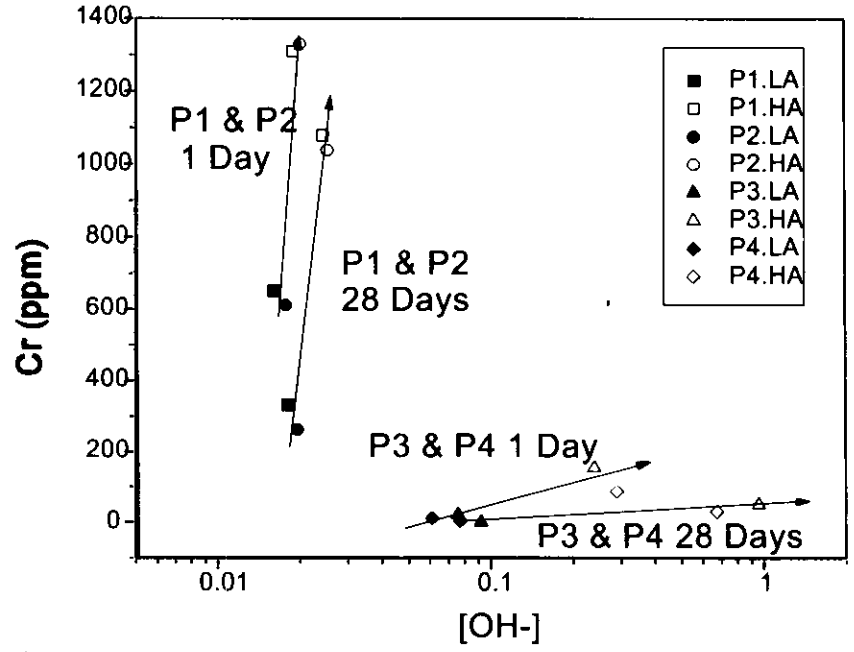
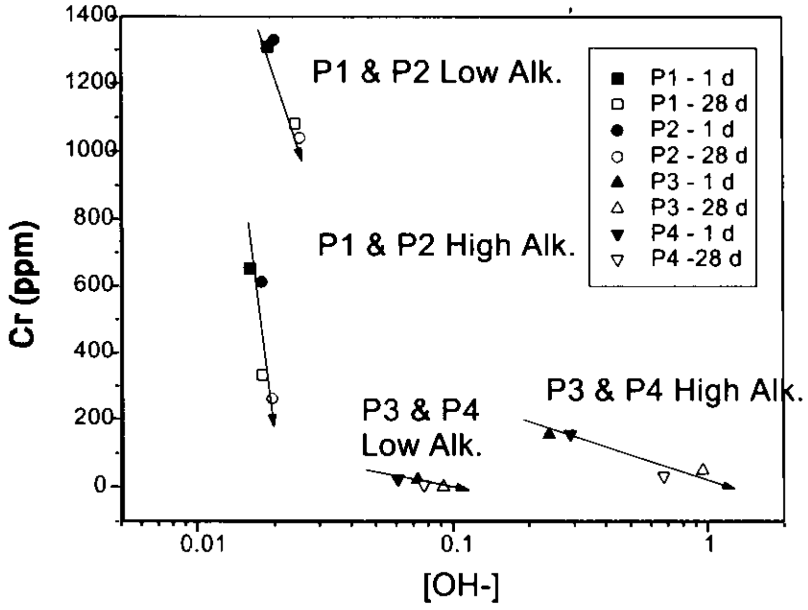


Figure 6. Schematic of pore expression apparatus.



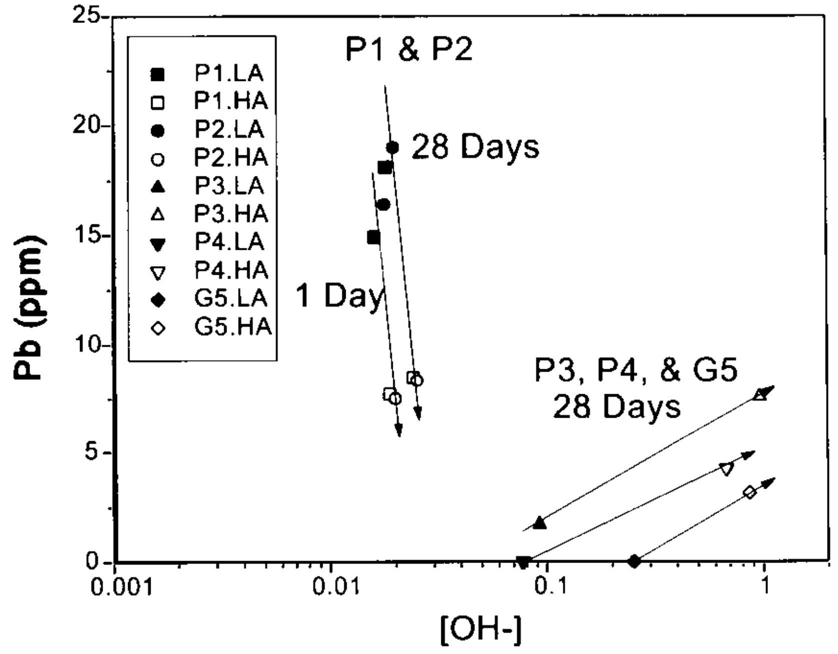
Note: Arrows indicate increasing alkali content.

Figure 7. Increase in chromium concentration of expressed pore solutions with alkali content of the expressed pore solution.



Note: Arrows indicate increasing alkali content of cement.

Figure 8. The effect of time on the chromium concentration in expressed pore solution.



Note: Arrows indicate increasing hydration time.

Figure 9. Dependence of lead concentration on the [OH-] of the expressed pore solutions.

Table 31. Composition of the solid residue retained after pore solution expression.

Waste	Cement	Hydration	pH start	[OH] end	pH end	Cd ppm	Pb ppm	Cr ppm	Ba ppm	TCLP Status
P1	Low Alk.	1	2.92	0.0239	12.37*		0.296	19.11	0.43	Failed Cr
P1	High	1	2.92	0.0174	12.24*		0.142	18.81	0.41	Failed Cr
P1	Low Alk.	28	2.91	0.0188	12.27*		0.18	23.83	0.32	Failed Cr
P1	High	28	2.91	0.0163	12.21*		0.13	9.87	0.38	Failed Cr
P2	Low Alk.	1	2.90	0.0261	12.41*		0.42	20.47	0.51	Failed Cr
P2	High	1	2.90	0.0207	12.31*		0.25	14.96	0.53	Failed Cr
P2	Low Alk.	28	2.91	0.0195	12.29*		0.19	24.84	0.37	Failed Cr
P2	High	28	2.91	0.0210	12.32*		0.16	10.80	0.52	Failed Cr
G5	Low Alk.	1	2.84		10.50		<0.066	<0.007	0.28	Passed
G5	High	1	2.84		11.74		<0.066	0.045	0.31	Passed
G5	Low Alk.	28	2.87		10.09		<0.066	0.016	0.34	Passed
G5	High	28	2.87		11.70		<0.066	0.024	0.42	Passed
G6	Low Alk.	1	2.87		10.05		<0.066	0.007	0.31	Passed
G6	High	1	2.87		11.70		<0.066	0.063	0.30	Passed
S7	Low Alk.	1	2.86		9.65		<0.066	0.142	0.46	Passed
S7	High	1	2.83		11.70		<0.066	0.288	0.46	Passed
S8	Low Alk.	1	2.85		10.57		<0.066	<0.007	0.36	Passed
S8	High	1	2.85		11.82		<0.066	0.032	0.47	Passed
TCLP Limits						1.0	5.0	5.0	100.0	

*calculated

Table 32. TCLP results for virgin concrete waste samples without pore solution expression.

Waste	Cement	Hydration days	pH start	[OH] end	pH end	Cd ppm	Pb ppm	Cr ppm	Ba ppm	TCLP Status
P1	Low Alk	77	2.90	0.0246	12.39*		0.255	22.72	0.39	Failed Cr
P1	High	77	2.90	0.0118	12.07*		<0.066	15.07	0.37	Failed Cr
P2	Low Alk.	28	2.91	0.0278	12.44*		0.29	16.11	0.43	Failed Cr
P2	High	28	2.91	0.0141	12.14*		0.08	15.32	0.36	Failed Cr
TCLP Limit						1.0	5.0	5.0	100.0	
*calculated										

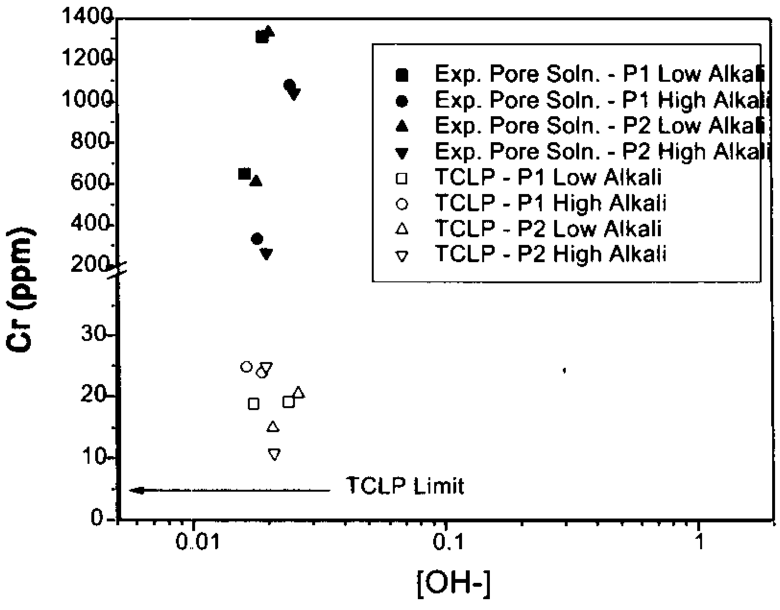
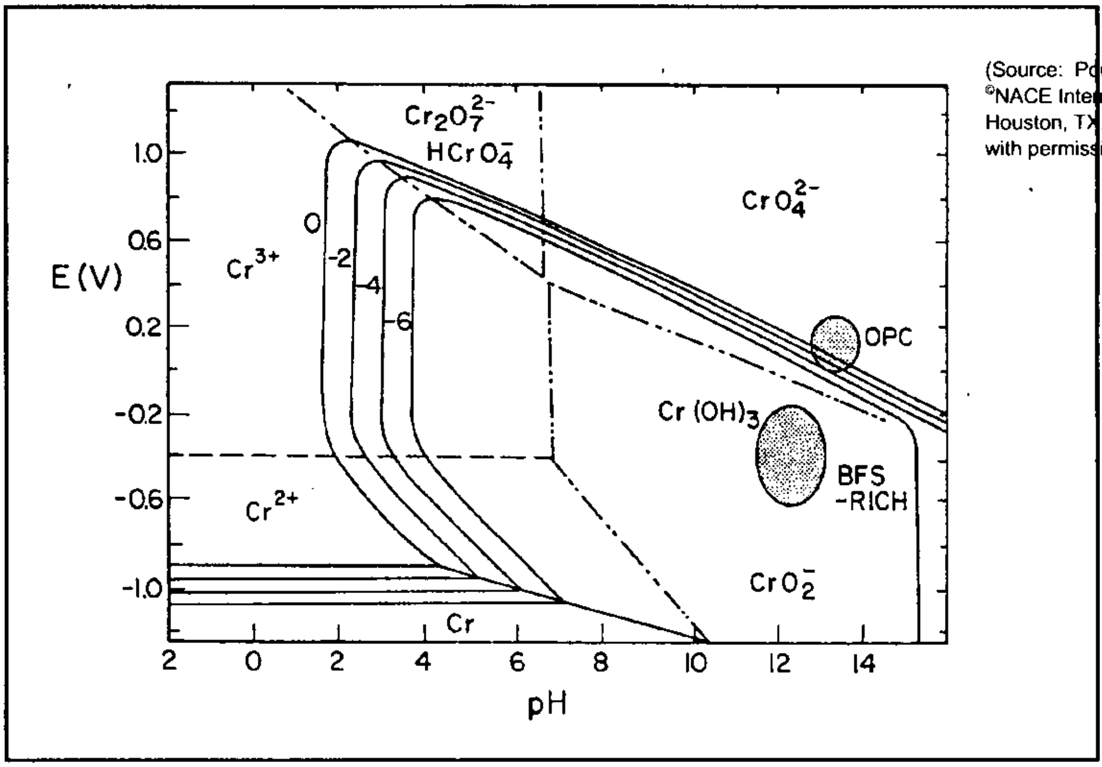


Figure 10. Control of the chromium concentration of both the expressed pore solution and TCLP by the [OH-].



(Source: Pourbaix 1974. ©NACE International, Houston, TX. Reprinted with permission.)

Figure 11. Potential pH for system chromium in waste.

Table 33. X-ray fluorescence analysis of blast furnace slag.

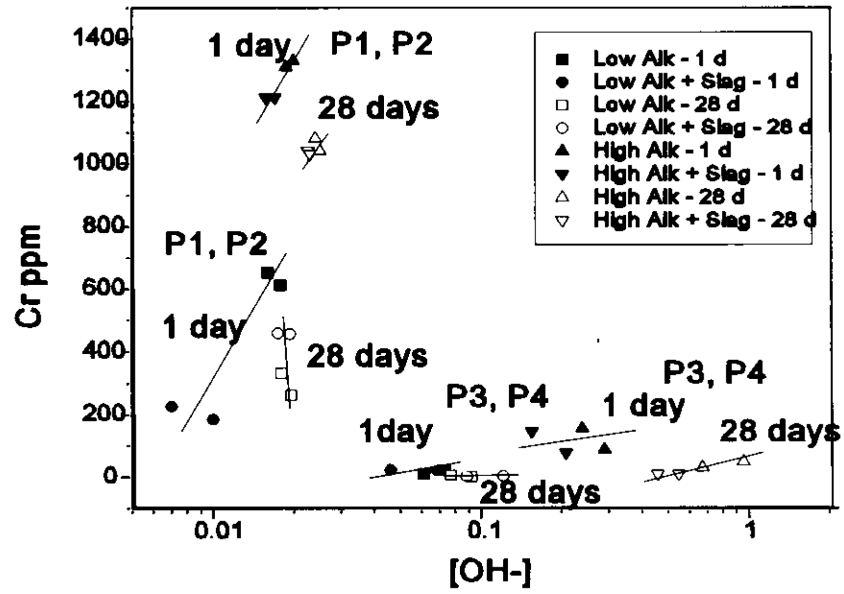
Oxide Equivalent	Blast Furnace Slag
SiO_2	37.55
Al_2O_3	7.45
Fe_2O_3	0.18
CaO	39.07
MgO	11.32
K_2O	0.36
Na_2O	0.30
TiO_2	0.37
P_2O_5	0.01
MnO	0.55
SO_3	2.80
Total	99.96

Table 34. Chemical analysis of expressed pore solutions in high-alkali cement with blast furnace slag (75% waste, 19% cement, 6% slag).

Waste	Cement matrix	Hydration Days	Water/Cement Wt., Vol.	$[OH^-]$	pH	Cr (mg/l)
P1	High Alkali	1	1.21, 3.79	0.0188	12.27*	1310
P1	H.A. + Slag	1	1.21, 3.79	0.0188	12.27*	1210
P1	High Alkali	28	1.21	0.0242	12.38*	1080
P1	H.A. + Slag	28	1.24	0.0227	12.35*	1040
P2	High Alkali	1	1.21, 3.79	0.0200	12.30*	1330
P2	H.A. + Slag	1	1.21, 3.79	0.0171	12.23*	1210
P2	High Alkali	28	1.21	0.0252	12.40*	1040
P2	H.A. + Slag	28	1.24	0.0231	12.36*	1030
P3	High Alkali	1	0.69, 2.15	0.2390	13.38*	155
P3	H.A. + Slag	1	0.71, 2.15	0.1550	13.19*	144
P3	High Alkali	28	0.69	0.9572	13.98*	49.5
P3	H.A. + Slag	28	0.70	0.5486	13.74*	9.22
P4	High Alkali	1	0.69, 2.15	0.2900	13.46*	87.5
P4	H.A. + Slag	1	0.69, 2.15	0.2080	13.32*	76.6
P4	High Alkali	28	0.69	0.6730	13.83*	30.61
P4	H.A. + Slag	28	0.70	0.4578	13.66*	8.37

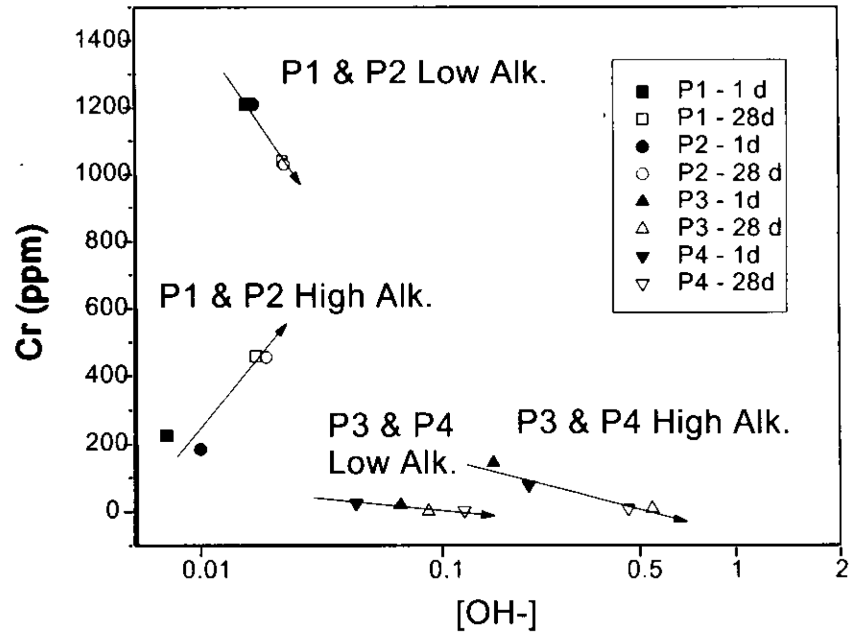
Table 35. Chemical analysis of expressed pore solutions in low-alkali cement with blast furnace slag (75% waste, 19% cement, 6% slag).

Waste	Cement matrix	Hydration Day	Water/Cement Wt., Vol.	$[OH^-]$	pH	Cr (mg/l)
P1	Low Alkali	1	1.22, 3.79	0.016	12.20*	652
P1	L.A. + Slag	1	1.22, 3.79	0.007	11.84*	227
P1	Low Alkali	28	1.22	0.018	12.25*	333
P1	L.A. + Slag	28	1.22	0.0175	12.24*	459
P2	Low Alkali	1	1.22, 3.79	0.0178	12.25*	612
P2	L.A. + Slag	1	1.22, 3.79	0.010	12.00*	185
P2	Low Alkali	28	1.22	0.0196	12.29*	263
P2	L.A. + Slag	28	1.25	0.0194	12.28*	456
P3	Low Alkali	1	0.69, 2.15	0.0728	12.86*	21.5
P3	L.A. + Slag	1	0.69, 2.15	0.0688	12.84*	20.9
P3	Low Alkali	28	0.69	0.09214	12.96*	N/A
P3	L.A. + Slag	28	0.68	0.08845	12.95*	2.32
P4	Low Alkali	1	0.69, 2.15	0.0610	12.78*	11.8
P4	L.A. + Slag	1	0.71, 2.15	0.0460	12.66*	23.3
P4	Low Alkali	28	0.69	0.07731	12.89*	5.26
P4	L.A. + Slag	28	0.71	0.1214	13.08	3.02



Note: Lines link cements having similar alkali contents and hydration times.

Figure 12. Effects of slag addition on [OH-] and chromium concentration of expressed pore solution.



Note: Arrows indicate increasing time.

Figure 13. Effects of hydration on [OH-] and chromium concentrations of expressed pore solutions.

Table 36. TCLP results for solid residue retained after pore solution expression (75% waste, 19% cement, 6% slag).

Waste	Cement	Slag	Hydration Days	pH Start	$[OH^-]$ End	pH End*	Cr (mg/l)	TCLP Status
P1	L.A.	Slag	1	2.92	0.0164	12.2	15.51	Failed Cr
P1	H.A.	Slag	1	2.92	0.0082	11.9	16.00	Failed Cr
P2	L.A.	Slag	1	2.90	0.0175	12.2	16.92	Failed Cr
P2	H.A.	Slag	1	2.90	0.0097	12.0	23.16	Failed Cr
P1	L.A.	Slag	28	2.89	0.0158	12.2	17.38	Failed Cr
P1	H.A.	Slag	28	2.89	0.0059	11.8	7.72	Failed Cr
P2	L.A.	Slag	28	2.91	0.0210	12.3	10.8	Failed Cr
P2	H.A.	Slag	28	2.91	0.0110	12.0	9.00	Failed Cr
TCLP Limit							5.00	

*pH calculated from ionic concentrations

Table 37. TCLP results for virgin concrete waste samples (75% waste, 19% cement, 6% slag).

Waste	Cement	Slag	Hydration Days	pH Start	$[OH^-]$ End	pH End*	Cr (mg/l)	TCLP Status
P2	L.A.	No	28	2.92	0.0278	12.4	16.11	Failed Cr
P2	H.A.	No	28	2.92	0.0174	12.1	15.23	Failed Cr
P2	L.A.	Slag	28	2.92	0.0234	12.4	15.99	Failed Cr
P2	H.A.	Slag	28	2.92	0.0094	12.0	19.42	Failed Cr
TCLP Limit							5.00	

*pH calculated from ionic concentrations

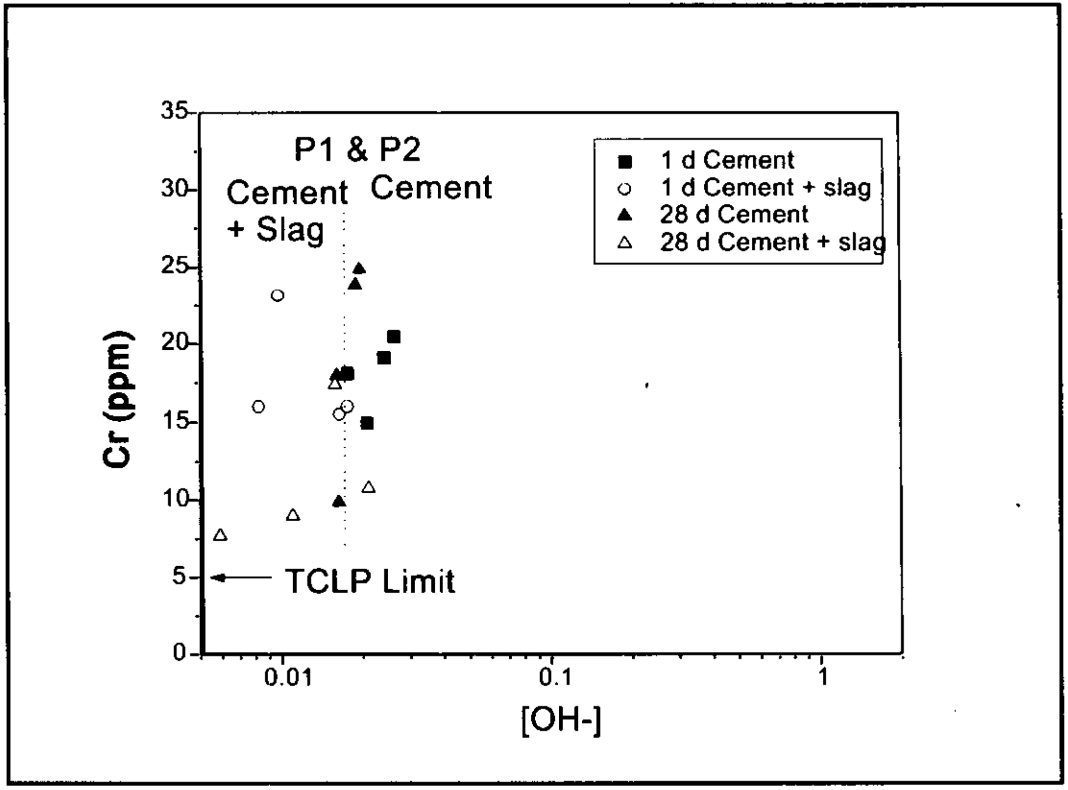


Figure 14. Effects of blast furnace slag additions on final [OH-] and chromium concentrations of the TCLP extraction fluid.

9 Chemical Stabilization, Fixation, and Recycling

Background

Red River Army Depot (RRAD) is the Army Center of Technical Excellence (CTX) for chemical stabilization of blast media waste. RRAD has conducted an evaluation of a chemical stabilization and fixation process. The treatment process reduces the level of leachable contaminants, allowing the waste to be classified as non-RCRA, which permits disposal in a Class II landfill. RRAD has received approval from the Texas Natural Resource Conservation Commission to use a Class II landfill for its chemically stabilized paint blast media waste. Chemical stabilization and fixation is not waste-specific.

Process

RRAD contracted for chemical stabilization and fixation services with Perma-Fix Environmental Services Inc., Grand Prairie, TX. The Perma-Fix proprietary two-step process involves chemical reduction followed by fixation. The process is conducted in an onsite mobile unit. The ingredients are properly mixed and poured in containers of 20–30 cu yd.[*] The containers are covered and stored onsite until analytical data are received. If the waste is classified as non-RCRA, it is disposed of in a Class II landfill.

Between 1 February 1994 and 1 May 1994 RRAD treated and disposed of (onsite) 170,000 kg of paint blast media waste. The treatment costs were estimated to be $0.33/kg. Cost savings obtained using chemical stabilization, fixation, and disposal in an onsite Class II landfill were estimated at $240,000. Based on the approximately 340,000 kg of paint blast media used in calendar year 1993, the estimated annual cost savings using the Perma-Fix process at RRAD are $480,000.

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[*] 1 cu yd = 0.7646 m^3.

USACERL personnel observed the Perma-Fix process at RRAD in July 1994. Samples of both untreated paint blast media wastes and of wastes treated using the Perma-Fix process were obtained and chemically analyzed. In addition to dry blast media waste, a blast media wash sludge is generated at RRAD. This sludge is generated from water jet washing used to remove residual media from vehicles after abrasive blasting. The principal blast media wastes at RRAD consist of sand and garnet.

Chemical analysis indicated that samples of paint blast media waste and blast media wash sludge contained high concentrations of Cr and Pb contaminants (Table 38). All samples of paint blast media waste and one sample of blast media wash sludge failed TCLP for Cd and/or Cr. Samples treated by the Perma-Fix process successfully met TCLP levels for the eight RCRA metals tested. The petroleum hydrocarbon content determined for the blast media wash sludge passed EPA disposal limits (1500 mg/kg) for both the untreated and treated sludge (Table 39).

Discussion

Perma-Fix chemical stabilization and fixation has been found to yield abrasive paint blast media wastes nonleachable by TCLP for the 8 RCRA metals. The use of the Perma-Fix chemical stabilization and fixation process is recommended for the treatment of paint blast media wastes contaminated with the eight RCRA metals. Other commercial chemical stabilization and fixation processes may also be suitable. Additional cost savings can accrue with disposal at an onsite Class II landfill. Paint blast media waste contaminated with hydrocarbons in excesses of EPA disposal limits may require additional treatment prior to disposal.

Table 38. RRAD metals data for the Perma-Fix stabilization and fixation process.

Sample	Test	As (ppm)	Ba (ppm)	Cd (ppm)	Cr (ppm)	Pb (ppm)	Hg (ppm)	Se (ppm)	Ag (ppm)	Status
Wash Sludge 1	Total Metals	<150	110	<75	880	390	<1.0	<150	<75	
Wash Sludge 2	Total Metals	<150	220	<75	2400	940	<1.0	<150	<75	
Wash Sludge 3	Total Metals	<150	<75	<75	470	250	<1.0	<150	<75	
Wash Sludge 1	TCLP	<0.50	1.2	0.39	0.84	1.3	<0.002	<0.10	<0.50	Passed
Wash Sludge 2	TCLP	<0.50	1.0	2.4	2.8	1.6	<0.002	<0.10	<0.50	Failed Cd
Wash Sludge 3	TCLP	<0.50	<1.0	0.46	<0.50	<0.50	<0.002	<0.10	<0.50	Passed
Treated Wash Sludge A	Total Metals	<150	320	<75	520	250	<1.0	<150	<75	
Treated Wash Sludge B	Total Metals	<150	350	<75	520	270	<1.0	<150	<75	
Treated Wash Sludge A	TCLP	<0.50	<1.0	1.04	<0.50	<0.50	<0.002	<0.10	<0.50	Passed
Treated Wash Sludge B	TCLP	<0.50	<1.0	0.52	<0.50	<0.50	<0.002	<0.10	<0.50	Passed
Blast Waste 1	Total Metals	<150	510	<75	5700	1800	<1.0	<150	<75	
Blast Waste 2	Total Metals	<150	490	<75	6200	1700	<1.0	<150	<75	
Blast Waste 1	TCLP	<0.50	1.3	7	7.9	6	<0.002	<0.10	<0.50	Failed Cd, Cr
Blast Waste 2	TCLP	<0.50	1.3	7.2	8.2	6.1	<0.002	<0.10	<0.50	Failed Cd, Cr
Treated Blast Waste A	Total Metals	<150	730	<75	2900	730	<1.0	<150	<75	
Treated Blast Waste B	Total Metals	<150	<75	<75	<75	<75	<1.0	<150	<75	
Treated Blast Waste A	TCLP	<0.50	<1.0	0.12	<0.50	<0.50	<0.002	<0.10	<0.50	Passed
Treated Blast Waste B	TCLP	<0.50	<1.0	<0.10	4.3	3.1	<0.002	<0.10	<0.50	Passed
	TCLP LIMIT	5.0	100.0	1.0	5.0	5.0	0.2	1.0	5.0	

Table 39. RRAD hydrocarbons data for the Perma-Fix stabilization and fixation process.

Sample	Test	Method	H-C's (mg/kg)	Limit (mg/kg)
Wash Sludge 1	Total Hydrocarbon	EPA 418.1	560	1500
Wash Sludge 2	Total Hydrocarbon	EPA 418.1	560	1500
Treated Wash Sludge A	Total Hydrocarbon	EPA 418.1	860	1500
Treated Wash Sludge B	Total Hydrocarbon	EPA 418.1	710	1500

10 Lease and Recycle of Plastic Blast Media

Background

This alternative to separation and treatment involves the leasing of plastic media to the Army depot. The depot uses the blast media in much the same way as purchased media, with the exception that the used media is returned to the manufacturer for reprocessing. It is acceptable for the returned blast media waste to contain paint residues and heavy metal contaminants—even at hazardous concentrations. If 100% of the returned blast media, including paint residue and contaminants, are used or reused as ingredients in an industrial process to make new products, the used media is, according to interpretations of RCRA Section 261.2(e), not considered to be a solid or hazardous waste (Neitzel 1993).

Commercial Processes

Two commercial lease/recycle processes have been identified:

1. U.S. Technology Corp., Canton, OH, uses spent paint blast media as filler in the manufacturing of molded plastic products. All processing is done in the United States.
2. Solidstrip, Inc., Newark, DE, ships spent paint blast media to a processing facility where it is broken down into methylmethacrylate monomer, which in turn is used to make acrylic sheet stock. The processing is done at a facility in Bombay, India.

Personnel at Corpus Christi Army Depot (CCAD) reviewed these commercially available lease/recycle programs and noted the advantages and disadvantages.

Advantages:

- The implementation of lease/recycle agreements is fully compatible with current paint blast operations.
- All types of plastic blast media used at Army depot facilities can be recycled by U.S. Technology Corp.

- The U.S. Technology Corp. process uses the spent plastic blast media in an industrial process to produce cast plastic products. U.S. Technology Corp. assumes liability for the spent media, so the liability of the Army facility is limited.
- The U.S. Technology Corp. plant is located in Canton, OH, and is regulated both by the Federal EPA and the Ohio State EPA.
- The U.S. Technology Corp. process has received approval from the Texas Water Commission for the use at CCAD.

Disadvantages:

- Solidstrip will also recycle thermoset media in a manner similar to U.S. Technology Corp.
- The Solidstrip process accepts only Type V thermoplastic acrylic media.
  The polymer cracking process used on Type V acrylic media may possibly be classified as a reclamation process such that the original purchaser may retain liability for the waste. The liability issues of this process remain ambiguous.
- The Solidstrip processing facility is located in India, and is not subject to regulation by the Federal EPA.

Pricing of U.S. Technology Corp. plastic blast media lease/recycle program depends on the media type and size purchased, the expected overall volume of the purchases planned during the contract period, the quantity of the shipments both ways, and the shipping distance/freight costs. The annual price for the complete media supply and recycling program ranged between $2.40/lb to $2.80/lb.[*]

Discussion

The use of lease/recycle agreements for plastic media waste is recommended. Reuse of the spent blast media effectively eliminates the waste stream from the Army facility. The Solidstrip process accepts only one type of blast media waste and is less universally applicable than the U.S. Technology Corp. process. The ambiguous liability issues associated with the Solidstrip process must be resolved before the process could be implemented. The U.S. Technology Corp. process—and others like it that use spent media as filler in the subsequent manufacture of molded plastic parts—is a recommended alternative to landfilling.

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[*] 1 lb = 0.4536 kg.

11 Conclusions and Recommendations

Conclusions

In this project seven categories of processing and recycling options for hazardous paint blast waste media were investigated. The work included both laboratory investigations and evaluation of existing technologies including commercially available processes. It is concluded that most of the options studied are not suitable for Army requirements:

- physical separation processes could not effectively isolate hazardous components from plastic media blast wastes
- low-temperature ashing effectively reduced waste volumes but produced the air pollutants phenol and hydrogen cyanide, which could not be filtered out of the combustion gases
- chemical separation through acid extraction and digestion reduced heavy metal concentrations in waste samples by only a small fraction
- biodegradation through a proprietary microbial digestion process reduced the volume of starch-based blast media (ground walnut shells) only, but walnut shells are not a major depaint medium on Army depots; bioremediation in general is complex, and it requires special expertise and equipment not available at most Army depots
- self-encapsulation of plastic media blast waste has been found to be effective only for Type V thermoplastic media, making the technique of limited use on Army depots
- waste stabilized in Portland cement (and Portland cement blended with blast furnace slag) failed the TCLP for chromium.

A commercial chemical stabilization, fixation, and recycling process such as those described in Chapter 9 may be a suitable and cost-effective way for the Army to eliminate some hazardous waste streams from depot depaint operations. When plastic-based hazardous blast media waste is 100% reprocessed and incorporated into a new product, it leaves the waste-disposal regulatory jurisdiction of the Resource Conservation and Recovery Act (RCRA). It appears that some commercial options would relieve the Army of continuing liability for the affected hazardous wastes. However, each commercial process would have to be reviewed carefully for clarification of liability issues, regulation of the contractor, technical effectiveness, etc.

Recommendations

It is recommended that the Army should not at this time pursue further study of the unsuitable blast media waste treatment options listed above.

It is recommended that Army depot depaint operations consider processing hazardous blast media waste through properly regulated private-sector contractors that provide safe, effective, and economical stabilization, fixation, and recycling processes. Due consideration should include an appropriate legal review of liability and regulatory issues.

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Appendix A: TCLP Metals and Testing Results for Depot Blast Media Wastes

Table A1. Chemical analysis of Sacramento Army Depot blast media waste.

Depot	Material	Sample ID	Test	Lab	Date	As	Ba	Cd	Cr	Pb	Hg	Se	Ag	Status
SAAD	Plastic	800864	TCLP	Lab A	3/18/93	<0.100	0.369	6.23	189	<0.100	<0.001	<0.120	<0.170	Failed Cd, Cr
SAAD	Sand	800865	TCLP	Lab A	3/18/93	<0.100	1.62	0.669	1.04	<0.100	<0.001	<0.120	<0.170	Passed
SAAD	Plastic	800864	TCLP	Lab B	2/4/93			5.22	N/A	BDL				Failed Pb
SAAD	Sand	800865	TCLP	Lab B	2/4/93			0.5	1.49	BDL				Passed
		LIMIT	TCLP			5.0	100.0	1.0	5.0	5.0	0.2	1.0	5.0	
SAAD	Plastic	800864	Metals	Lab B	5/3/93			191.8	3100	3791.6				

Table A2. Chemical analysis of Anniston Army Depot inorganic blast media waste.

Depot	Material	Sample ID	Test	Lab	Date	As	Ba	Cd	Cr	Pb	Hg	Se	Ag	Status
ANAD	Coal Slag	800863	TCLP	Lab A	3/18/93	<0.100	2.12	0.628	0.947	4.96	<0.001	<0.120	<0.170	Cond. Pass
ANAD	Coal Slag	800863	TCLP	Lab A	4/30/93	<0.120	0.596	17.4	7.08	0.254	<0.0005	<0.120	<0.170	Fail Cd, Cr
ANAD	Walnut	800866	TCLP	Lab A	3/18/93	<0.100	0.314	0.374	1.78	0.201	<0.001	<0.120	<0.170	Passed
ANAD	Mg/Fe Silicates	800867	TCLP	Lab A	3/18/93	<0.100	0.229	<0.100	<0.100	<0.100	<0.001	<0.120	<0.170	Passed
ANAD	Steel	800868	TCLP	Lab A	3/18/93	<0.100	3.35	<0.130	<0.120	0.607	<0.001	<0.120	<0.170	Passed
ANAD	Coal Slag	800863	TCLP	Lab B	2/4/93			BDL	0.37	BDL				Passed
ANAD	Walnut	800866	TCLP	Lab B	2/4/93			0.35	1.49	BDL				Passed
ANAD	Mg/Fe Silicates	800867	TCLP	Lab B	2/4/93			0.165	1.67	BDL				Passed
ANAD	Steel	800868	TCLP	Lab B	2/4/93			BDL	BDL	BDL				Passed
		BLANK	TCLP	Lab B	2/4/93			BDL	BDL	BDL				Passed
		LIMIT	TCLP			5.0	100.0	1.0	5.0	5.0	0.2	1.0	5.0	
ANAD	Coal Slag	800863	Metals	Lab A	4/6/93	<25.0	145	386	259	40.7	<0.051	<25.0	<2.00	
ANAD	Coal Slag	800863	Metals	Lab B	5/3/93			8.6	280.5	727.8				
ANAD	Walnut	800866	Metals	Lab B	5/3/93			9.8	124.5	189.2				
ANAD	Mg/Fe Silicates	800867	Metals	Lab B	5/3/93			BDL	17.3	34.7				
ANAD	Steel	800868	Metals	Lab B	5/3/93			96.3	3000	7322.2				

Table A3. Chemical analysis of Anniston Army Depot organic blast media waste.

Depot	Material	Sample ID	Test	Lab	Date	As	Ba	Cd	Cr	Pb	Hg	Se	Ag	Status
ANAD	Walnut	800900	TCLP	Lab A	3/18/93	<0.100	0.291	0.187	1.26	0.185	<0.001	<0.120	<0.170	Passed
ANAD	Walnut	800901	TCLP	Lab A	3/18/93	<0.100	0.285	0.45	1.45	0.281	<0.001	<0.120	<0.170	Passed
ANAD	Walnut	800900	TCLP	Lab B	3/1/94			0.5	1.7	0.7				Passed
ANAD	Walnut	800901	TCLP	Lab B	3/1/94			0.7	1.7	1.1				Passed
		Blank	TCLP	Lab B	3/1/94			BDL	BDL	BDL				
		LIMIT	TCLP			5.0	100.0	1.0	5.0	5.0	0.2	1.0	5.0	
ANAD	Walnut	800900	Metals	Lab B	5/3/93			3.8	125.7	164.9				
ANAD	Walnut	800901	Metals	Lab B	5/3/93			BDL	BDL	229.2				

Table A4. TCLP analysis of Corpus Christi Army Depot blast media waste.

Depot	Material	Sample ID	Test	Lab	Date	As	Ba	Cd	Cr	Pb	Hg	Se	Ag	Status
CCAD	Glass	800958	TCLP	Lab A	6/30/93	<0.120	0.510	23.3	1.77	0.274	<0.0005	<0.120	<0.170	Failed Cd
CCAD	Plastic 5	800959	TCLP	Lab A	6/30/93	<0.180	2.07	1.40	179.0	<0.120	<0.0005	<0.120	<0.170	Failed Cd, Cr
CCAD	Plastic 2	800960	TCLP	Lab A	6/30/93	<0.120	0.525	0.499	10.7	<0.120	<0.0005	<0.120	<0.170	Failed Cr
CCAD	Glass	800961	TCLP	Lab A	4/13/93	<0.110	0.17	0.72	<0.10	5.05	<0.001	<0.110	<0.39	Failed Pb
CCAD	Plastic 5	800962	TCLP	Lab A	6/30/93	<0.120	1.83	1.17	127.0	<0.120	<0.0005	<0.120	<0.170	Failed Cd, Cr
CCAD	Mix	800963	TCLP	Lab A	6/30/93	<0.120	1.90	0.783	0.649	4.41	<0.0005	<0.120	<0.170	Passed
CCAD	Star Blast	800964	TCLP	Lab A	6/30/93	<0.120	0.790	0.783	2.51	0.146	<0.0005	<0.120	<0.170	Passed
CCAD	Glass	800958	TCLP	Lab B	3/22/93			31.6	2.3	0.7				Failed Cd
CCAD	Plastic 5	800959	TCLP	Lab B	3/22/93			1.8	199.5	0.1				Failed Cd, Cr
CCAD	Plastic 2	800960	TCLP	Lab B	3/22/93			0.6	15.1	0.1				Failed Cr
CCAD	Glass	800961	TCLP	Lab B	3/22/93			1.3	BDL	5.6				Failed Cd, Pb
CCAD	Plastic 5	800962	TCLP	Lab B	3/22/93			1.5	112.1	0.1				Failed Cd, Cr
CCAD	Mix	800963	TCLP	Lab B	3/22/93			27.1	7.5	0.3				Failed Cd, Cr
CCAD	Star Blast	800964	TCLP	Lab B	3/22/93			1.3	4.0	0.2				Failed Cd
		Limit	TCLP			5.0	100.0	1.0	5.0	5.0	0.2	1.0	5.0	

Table A5. Metals analysis of Corpus Christi Army Depot blast media waste.

Depot	Material	Sample ID	Test	Lab	Date	As	Ba	Cd	Cr	Pb	Hg	Se	Ag	Status
CCAD	Glass	800958	Metals	Lab A	6/30/93	<25.0	6.17	472	91.4	13.6	<0.051	<25.0	<2.00	
CCAD	Plastic 5	800959	Metals	Lab A	6/30/93	<25.0	366	115	5370	1990	<0.051	<25.0	<2.00	
CCAD	Plastic 2	800960	Metals	Lab A	6/30/93	<25.0	9.5	10.9	188	8.97	<0.051	<25.0	<2.00	
CCAD	Glass	800961												
CCAD	Plastic 5	800962	Metals	Lab A	6/30/93	<25.0	236	42.9	3320	856	<0.051	<25.0	<2.00	
CCAD	Mix	800963	Metals	Lab A	6/30/93	<25.0	370	16.7	256	888	<0.051	<25.0	<2.00	
CCAD	Star Blast	800964	Metals	Lab A	6/30/93	<25.0	57.8	18.9	194.	300	<0.051	<25.0	<2.00	
CCAD	Glass	800958	Metals	Lab B	5/3/93			464.1	92.2	10.3				
CCAD	Plastic 5	800959	Metals	Lab B	5/3/93			88.2	5172.5	2553.6				
CCAD	Plastic 2	800960	Metals	Lab B	5/3/93			16.7	623.9	48.9				
CCAD	Plastic 2	800960	Metals	Lab B	5/3/93			19.2	730.4	54.3				
CCAD	Glass	800961	Metals	Lab B	5/3/93			20.7	17.9	142.1				
CCAD	Plastic 5	800962	Metals	Lab B	5/3/93			38.1	3495.9	898.8				
CCAD	Mix	800963	Metals	Lab B	5/3/93			6434.2	608.3	68.9				
CCAD	Star Blast	800964	Metals	Lab B	5/3/93			19.4	161.6	268.2				

Table A6. TCLP analysis of Sacramento Army Depot blast media waste.

Depot	Material	Sample ID	Test	Lab	Date	As	Ba	Cd	Cr	Pb	Hg	Se	Ag	Status
SAAD	Plastic	800969	TCLP	Lab A	4/13/93	<0.100	1.03	0.84	6.01	0.23	<0.001	<0.11	<0.39	Failed Cr
SAAD	Sand	800970	TCLP	Lab A	4/13/93	<0.100	1.26	0.75	0.94	0.79	<0.001	<0.11	<0.39	Passed
SAAD	Plastic	800968	TCLP	Lab B	4/16/93			1.5	11.0	BDL				Failed Cd, Cr
SAAD	Plastic	800969	TCLP	Lab B	4/16/93			1.0	8.0	BDL				Failed Cr
SAAD	Sand	800970	TCLP	Lab B	4/16/93			0.7	1.0	0.2				Passed
		BLANK	TCLP	Lab B	4/16/93			BDL	BDL	BDL				
		Limit	TCLP			5.0	100.0	1.0	5.0	5.0	0.2	1.0	5.0	
SAAD	Plastic	800968	Metals	Lab B	4/16/93			39.4	704	727..8				
SAAD	Plastic	800969	Metals	Lab B	4/16/93			20.9	448.3	389.2				
SAAD	Sand	800970	Metals	Lab B	4/16/93			14	79.3	105.3				

Table A7. TCLP analysis results for additional Corpus Christi blast media wastes.

Depot	Material	Sample ID	Test	Lab	Date	As	Ba	Cd	Cr	Pb	Hg	Se	Ag	Status
CCAD	Plastic	1093 A	TCLP	Lab A	11/9/93	<0.500	<10.0	7.01	<0.500	0.675	<0.002	<0.100	<0.500	Failed Cd
CCAD	Plastic	1093 B	TCLP	Lab A	11/9/93	<0.500	<10.0	0.329	5.07	<0.500	<0.002	<0.100	<0.500	Failed Cr
		Limit	TCLP			5.0	100.0	1.0	5.0	5.0	0.2	1.0	5.0	
CCAD	Plastic	1093 A	Metals	Lab A	11/9/93	<4.00	6.20	160	3.00	26.0	0.259	<4.00	14.2	
CCAD	Plastic	1093 B	Metals	Lab A	11/9/93	<4.00	<4.00	2.52	41.5	9.36	<0.050	<4.00	<2.00	

Table A8. TCLP and metals test results for Corpus Christi Army Depot blast media waste.

Depot	Material	Sample ID	Test	Lab	Date	As	Ba	Cd	Cr	Pb	Hg	Se	Ag	Status
CCAD	Plastic	Plastic 1	TCLP	Lab C	5/12/94	<0.50	<1.0	1.3	66	<0.50	<0.002	<0.10	<0.50	Failed Cd, Cr
CCAD	Plastic	Plastic 3	TCLP	Lab C	5/25/94	<0.50	1.1	1.9	78	<0.50	<0.002	<0.10	<0.50	Failed Cd, Cr
		Limit	TCLP			5.0	100.0	1.0	5.0	5.0	0.2	1.0	5.0	
CCAD	Plastic	Plastic 1	Metals	Lab C	5/12/94	<2.0	330	74	2900	2900	<1.0	<2.0	<2.0	
CCAD	Plastic	Plastic 3	Metals	Lab C	5/25/94	<2.0	325	60	2700	2800	<1.0	<2.0	<2.0	

Table A9. Chemical analysis results for Tooele Army Depot blast media waste.

Depot	Material	Sample ID	Test	Lab	Date	As	Ba	Cd	Cr	Pb	Hg	Se	Ag	Status
TEAD	Plastic	T1	TCLP	Lab C	2/14/94	<5.0	<1.0	1.8	<0.50	<0.50	<0.002	<0.10	<0.5	Failed Cd
TEAD	Plastic	T2	TCLP	Lab C	2/14/94	<5.0	<1.0	1.5	<0.50	<0.50	<0.002	<0.10	<0.5	Failed Cd
TEAD	Ag	T3	TCLP	Lab C	2/14/94	<5.0	1.6	2.9	0.91	0.85	<0.002	<0.10	<0.5	Failed Cd
		Limit	TCLP			5.0	100.0	1.0	5.0	5.0	0.2	1.0	5.0	
TEAD	Plastic	T1	Metals	Lab C	2/14/94			220	2200	7000				
TEAD	Plastic	T2	Metals	Lab C	2/14/94			260	2400	7800				
TEAD	Ag	T3	Metals	Lab C	2/14/94			68	320	840				

Table A10. TCLP results for Red River Army Depot blast media waste.

Media	Date	Cd	Cr	Pb	TCLP Status
Steel	Apr.-94	190	BDL	BDL	Failed Cd
Sand/Garnet 1	Apr.-94	9.4	15	BDL	Failed Cd Cr
Sand/Garnet 2	Apr.-94	2.3	2	BDL	Failed Cd
Prefix	Apr.-94	BDL	BDL	BDL	Passed

Appendix B: Detailed Experimental Procedure for Low-Temperature Ashing (LTA)

Determination of Feed Material Mass During LTA

Samples of urea formaldehyde, acrylic, and ground walnut shell blast media were subjected to thermogravimetric (TG) analysis using a Netzsch Model 429 simultaneous thermal analysis instrument. Samples were heated in an air atmosphere with an airflow rate of 100 cc/minute. Samples ranging from 100–180 mg were weighed and heated at a rate of 10 °C per minute until no additional weight loss could be observed. Sample mass loss was expressed as a percentage of sample weight and in terms of percent sample weight/minute (see Figures 1, 2, and 3 in main text, Chapter 4).

Determination of Gaseous Volume Produced During LTA

Experiments were designed to simulate LTA conditions of the three paint blast media samples at 575 °C. Gaseous volumes generated during LTA of the media samples were calculated to estimate the actual gaseous volume that would be produced during waste processing of spent paint blast media. The experimental arrangement included charcoal-filtered high-purity compressed air delivered to the quartz tube housed in a tube furnace capable of achieving temperature of 1100 °C. Gaseous effluent and particulate generated during ashing were passed through a heat exchanger immersed in a water bath for cooling the effluent before mass-flow measurements. Mass-flow measurements were taken with a Sierra Instruments 820 mass-flow meter. Effluent gaseous volume of each sample was determined with a Waugh Controls V/F Integrator (basically, a digital counter). Each combustion experiment was timed with a stopwatch. Integrator count readings were taken at 0.5 minute intervals. Combustion effluent flow rates in liters/minute were calculated from integrated flow volume data and plotted versus time to generate the graphs shown in Figures B1 and B2. The total air volume passed through the quartz tube furnace during combustion experiments was subtracted from the total gaseous volume generated with each media sample to yield the net combustion volume produced from each sample.

Determination of Significant Volatile Organic Compounds (VOCs) Produced

Thermal desorption (TD) gas chromatography mass spectrometry (GC/MS) analyses were conducted on volatile organic compounds (VOCs) produced from LTA of test media and subsequently collected on triple sorbent traps (TSTs). LTA combustion experiments were carried out at air purge flow rates of 2 L/min. VOCs were sampled immediately after smoke was generated and mixed inside a sealed chamber. Triple sorbent traps (76 mm x 4 mm inside diameter) containing Carbotrap C, Carbotrap, and Carbosieve S-III were prepared and conditioned according to the procedure described in Oak Ridge National Laboratory (ORNL) Standard Operating Procedure AC-OP-000-0907. Before sample collection, two blank traps randomly selected from a batch of 30 freshly prepared traps were analyzed by TD and GC/MS to ensure the cleanliness of the traps.

VOCs collected on the triple sorbent traps were thermally desorbed and transferred to GC capillary column for subsequent GC/MS analysis. GC/MS analysis was carried out on an HP 5895 GC/MS system equipped with dual ion source. Typically, a TST was first purged with helium at a flow rate of 200 ml/min for 5 minutes in the same direction of the sampling flow to remove excess absorbed moisture. The trap was then placed in a tube furnace held at 300 °C and purged with helium at a flow rate of 50 ml/min. for 5 minutes in the opposite direction of sampling flow. The desorbed material was transferred directly through a quartz glass liner in the GC injection port to the Cryoloop at the head of the capillary column (60 m × 0.32 mm inside diameter fused-silica capillary column bonded with DB-5 of 1.0 μm film thickness). The cryoloop was constructed with a 20 cm stainless steel tube (0.04 in. inside diameter [ID], 1/16 in. outside diameter [OD]), and was immersed in a liquid nitrogen bath during the desorbing process. GC oven temperature program was initiated when the liquid nitrogen temperature bath was removed from the cryoloop. The GC oven temperature was held at 50 °C for 5 minutes and then increased to 250 °C at a rate of 10 °C/minutes. Electron impact (EI) mass spectra of the eluate was obtained with an electron energy of 70 eV and emission current of 300 μA. Source temperature was set at 200 °C. GC injector and transfer line temperatures were set at 280 °C. Mass spectral data was acquired over a mass range or 15-500 amu at a scan rate of 266 amu/sec for all but the TST #29 sample trap (the first trap analyzed). TST #29 (Agrashell) was scanned over a mass range of 30-500 amu, the mass range normally employed for routine analysis in this laboratory. Chamber blank traps which were collected before sample combustion were also analyzed in the same manner as the sample traps. In order to estimate the quantities of major components present in the sample traps, a blank TST was soiled with 0.5 ml of 3.8 μg/ml d_6-benzene vapor phase standard which was generated using the static dilution method. Quantities of the major components in the sample traps (measured in terms of μg/L) were estimated based on the response factor of d_6-benzene as an external calibration.

The reconstructed total ion chromatograms from a chamber blank and for the vapor phase samples generated from the combustion of paint blast materials of the ground walnut shell, acrylic, and urea formaldehyde media are presented in Figures B3, B4, and B5. Because of the complex and overly abundant constituents present in each of the vapor phase samples, the effort was focused on the identification of major components. Those components represent a chromatographic area equal to or greater than 1.0% of the total chromatographic area.

The selective ion mode was used to obtain mass chromatograms of m/z 27 and 26 (the two most abundant ions for hydrogen cyanide) to search for the presence of hydrogen cyanide (Figure B6). As shown in Figure B7, mass spectra retrieved from the component eluting at 2.57 min. showed an m/z ratio of 27 ion (100 percent) and an m/z 26 ion (41 percent), which may be related to hydrogen cyanide. This component, representing less than 0.2% of the total chromatographic area, also contained ions generated from water (m/z 18), oxygen (m/z 32, 16), nitrogen (m/z 28), and carbon dioxide (m/z 44). A similar procedure was employed to search for the presence of formaldehyde; none of the early eluting components exhibited the expected characteristic ions generated from formaldehyde.

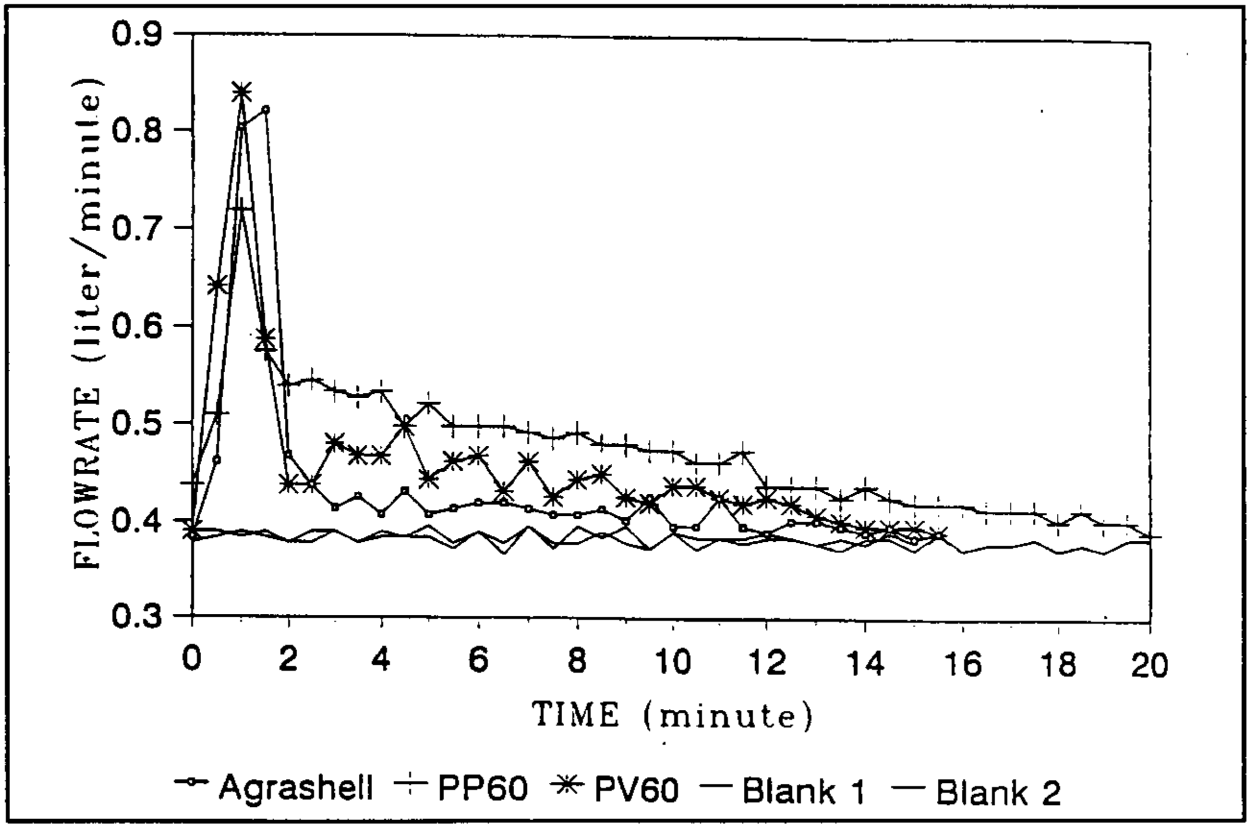

Figure B1. Combustion gas effluent flow rate plotted against time.

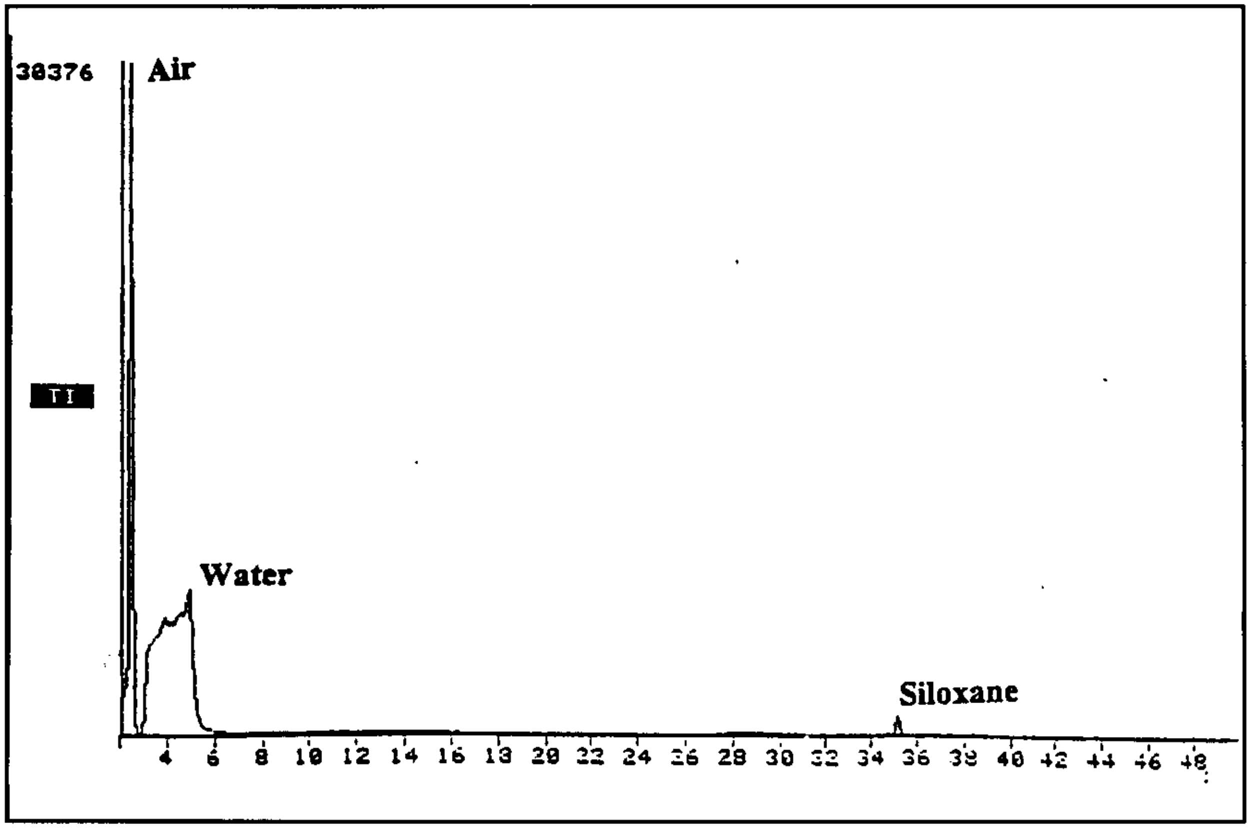

Figure B2. Gas chromatography, chamber blank.

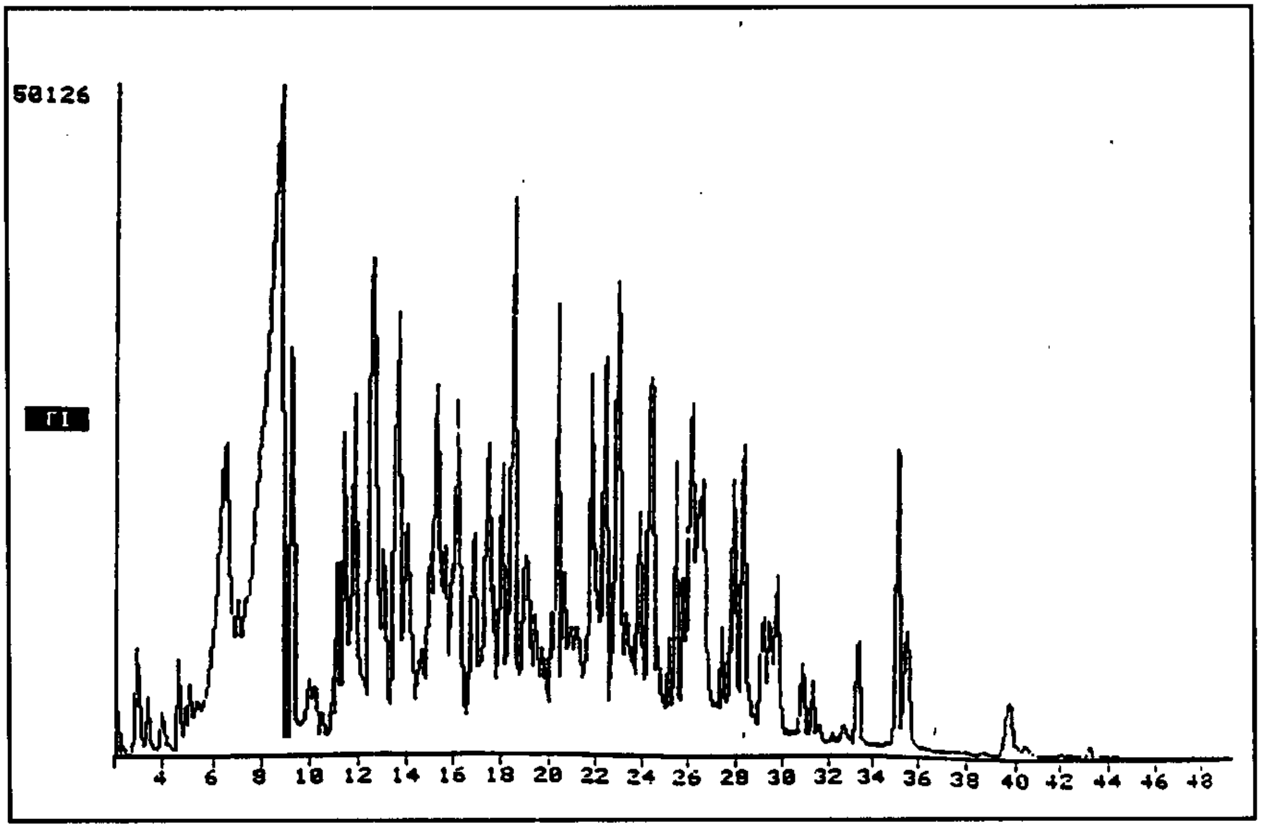

Figure B3. Gas chromatography plot for ground walnut shell blast media treated with LTA.

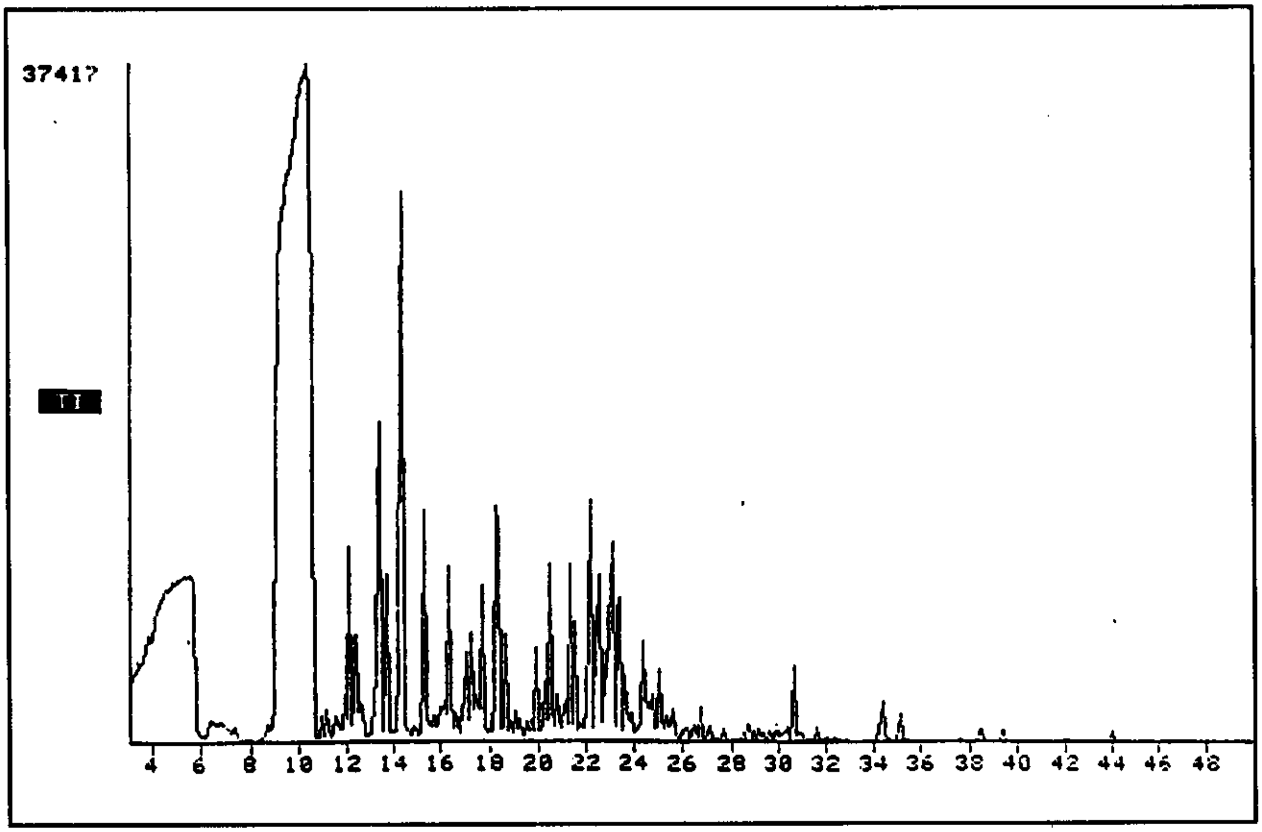

Figure B4. Gas chromatography plot for acrylic blast media treated with LTA.

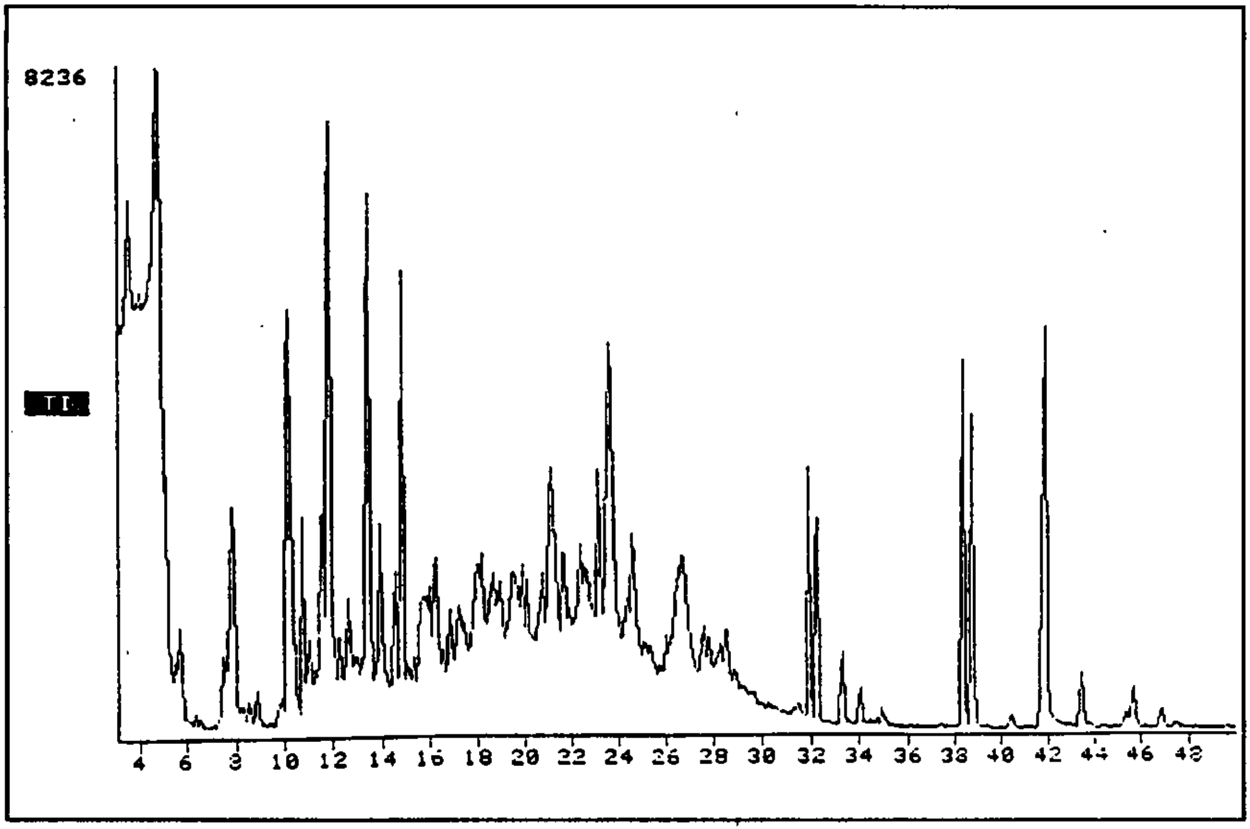

Figure B5. Gas chromatography plot for urea formaldehyde blast media treated with LTA.

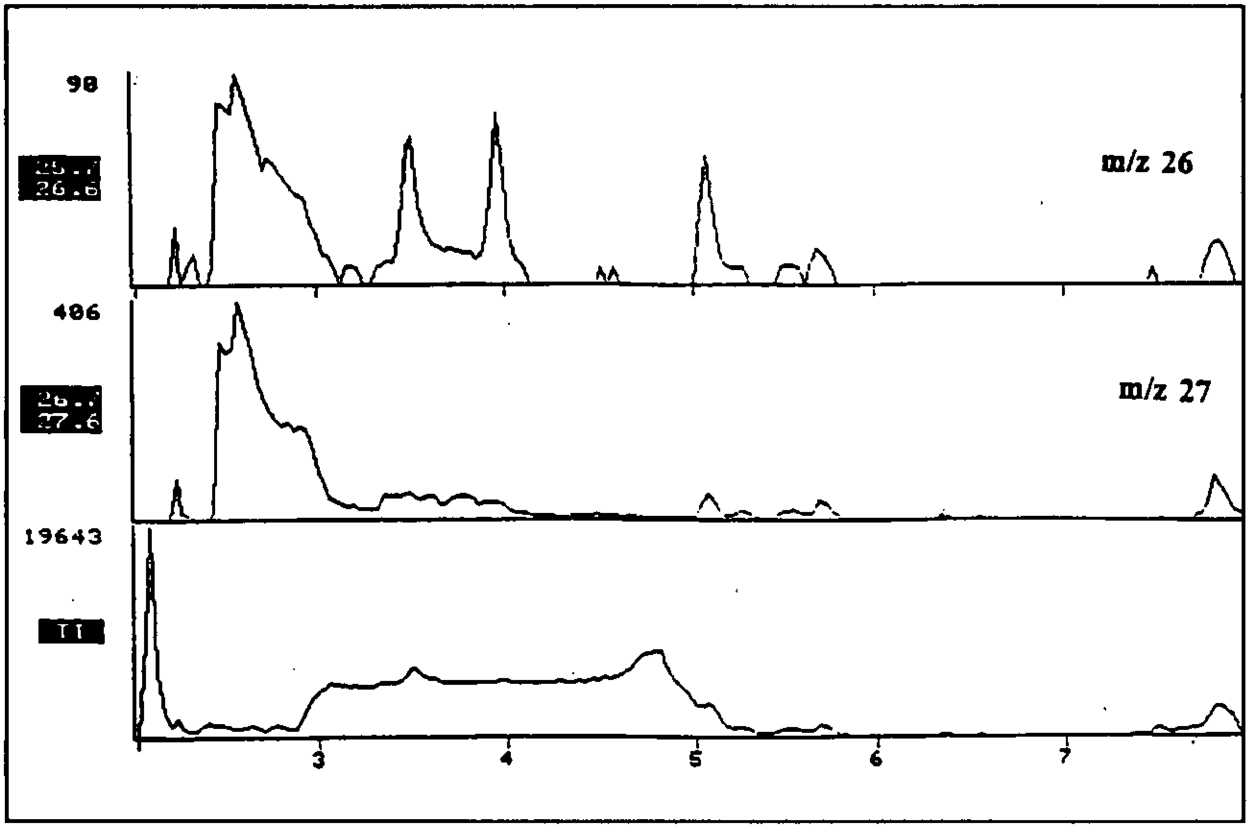

Figure B6. Mass chromatography plot for m/z 26 and m/z 27 treated with LTA.

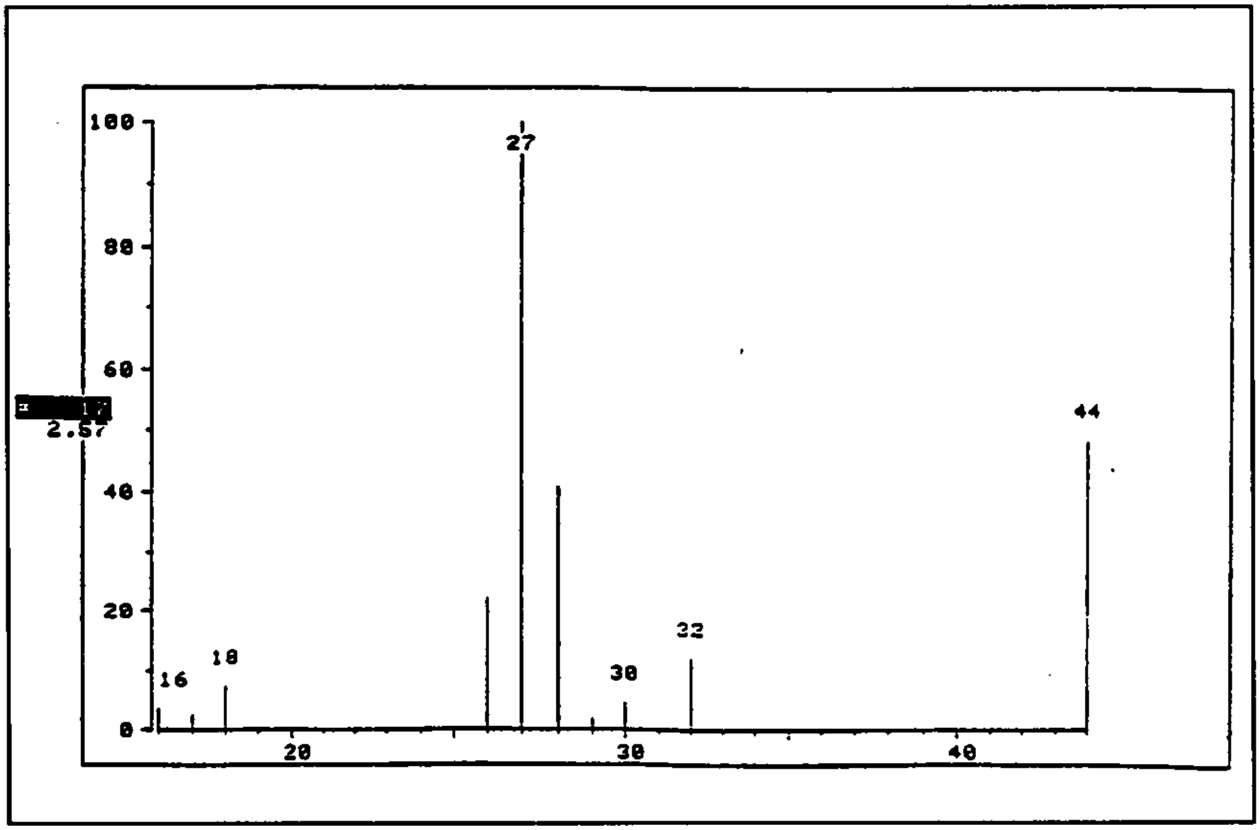

Figure B7. Electron impact mass spectrum for components at 2.57 minutes.

Appendix C: Data for Cement-Based Stabilization Studies

Table C1. Complete chemical results for cement-based stabilization process.

No.	METHOD	SAMPLE NAME	OHorpH	[OH]orpH	Cd	Pb	Cr	Ba	Ca	Al	K	Na	Si	S	Fe	Mg
			start	end	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm
10	TCLP	blank	4.91	4.88	<0.017	<0.066	<0.007									
11	TCLP	Pb3O4-Al2O3	4.89	5.20	0.037	0.24	0.379									
12	TCLP	ZnCrO4-Al2O3	4.91	5.36	0.047	0.068	4.399									
13	TCLP	Pb3O4-Al2O3	4.92	5.22	0.028	0.30	0.214	Zn 17.57								
14	TCLP	ZnCrO4-Al2O3	4.93	5.35	0.034	<0.066	2.406	Zn 42.30								
15	TCLP	same13+0.450mgPb	4.91	5.23	0.027	0.36	0.193	Zn 17.01								
16	TCLP	same14+5.0mgCr	4.92	5.38	0.034	0.082	3.550	Zn 42.14								
17	TCLP	blank	4.88	4.88	<0.017	<0.066	<0.007									
18	TOTAL HNO3+HCl	Al2O3+Pb3O4(0.1%)			6	754	20									
19	TOTAL H2SO4	Al2O3+ZnCrO4(0.1%)			8		64									
20	TOTAL	Al2O3+Pb-LiBO2			10	740	92									
21	TOTAL	Al2O3+Cr-LiBO2			8	48	92									
22	PORE SOLUTION-S	Al2O3+Pb-0.1M1d	0.0902	0.0879	<0.017	2.13	0.009	Zn 9.76								
23	PORE SOLUTION-S	Al2O3+Pb-1M1d	0.8920	0.8910	<0.017	13.86	0.006	Zn 18.79								
24	PORE SOLUTION-S	Al2O3+Cr-0.1M1d	0.0902	0.0877	<0.017	0.72	1.094	Zn 15.20								
25	PORE SOLUTION-S	Al2O3+Cr-1M1d	0.8910	0.8870	<0.017	0.99	1.847	Zn 36.49								
26	PORE SOLUTION-S	1PM-1M1d	0.9953	0.952	0.214	81.44	45.62									
27	PORE SOLUTION-S	3PM-1M1d	0.9953	0.976	<0.017	16.24	12.83									
28	PORE SOLUTION-S	5GB-1M1d	0.9953	0.986	0.343	1.40	0.081									
29	PORE SOLUTION-S	7SB-1M1d	0.9953	0.986	<0.017	2.20	0.613									
30	TOTAL	8SB-LiBO2			86		40	704								
31	TOTAL	8SB-LiBO2			82		38	765								
32	TOTAL	Al2O3-LiBO2			8		51	Zn 313								
33	TOTAL	Al2O3-LiBO2			13		45	Zn 429								
34	TCLP	blank	4.91	4.92	<0.017	<0.066	<0.007									
35	TCLP	SAND-Pb	4.94	4.95	<0.017	2.77	<0.007	<0.03								
36	TCLP	35#+Pb-ICP	4.94	4.95	<0.017	9.33	<0.007									
37	TCLP	SAND-Cr	4.91	4.94	0.031	<0.066	2.40	Zn 28.80								
38	TCLP	37#+Cr+Zn-ICP	4.91	4.94	0.023	<0.066	4.96	Zn 51.46								
39	TCLP	same13#														
40	TCLP	same14#														
41	TCLP	39#+Pb-ICP				6.06										
42	TCLP	40#+Cr-ICP					4.72									
43	TCLP	1PM	4.89	5.25	4.90	<0.066	43.07	0.65								
44	TCLP	2PM	4.91	5.25	5.15	<0.066	44.73	0.74								
45	TCLP	3PM	4.92	4.96	1.35	<0.066	18.01	0.55								
46	TCLP	4PM	4.91	4.96	1.35	<0.066	16.32	0.56								
47	TCLP	5GB	4.90	5.00	28.17	4.86	0.16	0.19								
48	TCLP	6GB	4.90	4.93	1.93	0.24	0.03	0.17								
49	TCLP	7SB	4.90	4.98	0.62	0.18	0.47	1.03								
50	TCLP	8SB	4.90	4.93	4.85	0.10	0.10	0.30								
51	TCLP	blank	4.91	4.93	<0.017	0.40	<0.007	<0.03								
52	TCLP	51#+Pb+Cr-ICP			<0.017	4.81	4.52									

No.	METHOD	SAMPLE NAME	OHorpH start	[OH]orpH end	Cd ppm	Pb ppm	Cr ppm	Ba ppm	Ca ppm	Al ppm	K ppm	Na ppm	Si ppm	S ppm	Fe ppm	Mg ppm
53	TCLP	46#+Pb+Cr-ICP			1.27	4.44	20.43									
54	TCLP	50#+Pb+Cr-ICP			4.66	4.50	4.69									
55	PORE SOLUTION-S	1PM-0.1M1d	0.0993	0.0790	0.02	31.70	92.54	0.05								
56	PORE SOLUTION-S	2PM-0.1M1d	0.0993	0.0818	<0.017	25.69	88.48	0.04								
57	PORE SOLUTION-S	3PM-0.1M1d	0.0993	0.0929	<0.007	8.86	23.22	0.03								
58	PORE SOLUTION-S	4PM-0.1M1d	0.0993	0.0935	<0.007	8,91	21.72	<0.03								
59	ICP-STANDARD	8-element														
60	PORE SOLUTION-S	55#+8element			ICP?	ICP?	ICP?									
61	PORE SOLUTION-S	same#55			ICP?	ICP?	ICP?									
62	PORE SOLUTION-S	5GB-0.1M1d	0.0993	0.0968	<0.017	2.07	0.129	<0.03								
63	PORE SOLUTION-S	6GB-0.1M1d	0.0993	0.0983	<0.017	<0.066	0.032	<0.03								
64	PORE SOLUTION-S	7SB-0.1M1d	0.0993	0.0964	<0.017	0.42	1.258	<0.03								
65	PORE SOLUTION-S	8SB-0.1M1d	0.0993	0.0980	<0.017	0.12	0.144	<0.03								
66	PORE SOLUTION-S	1PM-1M28d	0.998	0.945	0.09	84.98	104.5	0.28								
67	PORE SOLUTION-S	2PM-1M28d	0.998	0.954	0.11	88,75	106.7	0.30								
68	PORE SOLUTION-S	3PM-1M28d	0.998	0.980	0.03	21.93	39.95	0.37								
69	PORE SOLUTION-S	4PM-1M28d	0.998	0.979	0.04	23.96	36.72	0.39								
70	ICP-STANDARD	8-element														
71	PORE SOLUTION-S	69#+8element			85%	97%	89.6%	102%								
72	ICP-same55#															
73	ICP-same56#															
74	ICP-same57#															
75	ICP-same58#															
76	ICP-same62#															
77	ICP-same63#															
78	ICP-same64#															
79	ICP-same65#															
80	ICP-same60#															
81	ICP-same61#															
82	PORE SOLUTION-S	5GB-1M28d	0.989	0.976	0.28	4.71	0.067	0.06								
83	PORE SOLUTION-S	6GB-1M28d	0.989	0.979	0.089	0.60	0.062	<0.03								
84	PORE SOLUTION-S	7SB-1M28d	0.989	0.975	0.019	2.01	1.44	0.29								
85	PORE SOLUTION-S	8SB-1M28d	0.989	0.977	0.018	0.48	0.22	0.08								
86	ICP-STANDARD	8-element														
87	ICP-STANDARD	Ag-Cr														
88	ICP	blank			<0.017	<0.066	<0.007	<0.030								
89	PORE SOLUTION-S	1PM-0.1M28d	0.0998	0.0687	0.029	30.68	89.06	0.03								
90	PORE SOLUTION-S	2PM-0.1M28d	0.0998	0.0685	0.026	27.62	86.87	0.03								
91	PORE SOLUTION-S	3PM-0.1M28d	0.0998	0.0887	7 <0.017	12.49	27.69	0.03								
92	PORE SOLUTION-S	4PM0.1M28d	0.0998	0.0894	<0.017	13.83	28,00	0.03								
93	PORE SOLUTION-S	85#+8-element														
94	PORE SOLUTION-S	5GB-0.1M28d	0.0998	0.0973	<0.017	3,74	0.12	<0.03								
95	PORE SOLUTION-S	6GB-0.1M28d	0.0998	0.0988	<0.017	0.10	0.038	<0.03								

No.	METHOD	SAMPLE NAME	OHorpH	[OH]orpH	Cd	Pb	Cr	Ba	Ca	Al	K	Na	Si	S	Fe	Mg
			start	end	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm
96	PORE SOLUTION-S	7SB-0.1M28d	0.0998	0.0957	<0.017	0.37	1.43	<0.03								
97	PORE SOLUTION-S	8SB-0.1M28d	0.0998	0.0977	<0.017	0.14	0.17	<0.03								
98	PORE SOLUTION-S	94#+8-element			93.7%	94.1%	103%	98.3%								
99	ICP-STANDARD	8-element														
100	PORE SOLUTION-S	same89#ICP														
101	PORE SOLUTION-S	same90#ICP														
102	PORE SOLUTION-S	1PM-1M1d	0.993	0.963	0.17	77.29	102.7	0.27								
103	PORE SOLUTION-S	2PM-1M1d	0.993	0.960	0.19	74.11	113.8	0.26								
104	PORE SOLUTION-S	3PM-1M1d	0.993	0.980	<0.017	18.01	38.14	0.25								
105	PORE SOLUTION-S	4PM1M1d	0.993	0.983	<0.017	18.41	32.00	0.24								
106	PORE SOLUTION-S	5GB-1M1d	0.993	0.989	0.31	1.42	0.053	0.05								
107	PORE SOLUTION-S	6GB-1M1d	0.993	0.993	0.28	0.37	0.038	0.04								
108	PORE SOLUTION-S	7SB-1M1d	0.993	0.984	<0.017	1.96	1.50	0.13								
109	PORE SOLUTION-S	8SB-1M1d	0.993	0.987	0.18	0.46	0.29	0.09								
110	PORE SOLUTION-S	109#+8-element			78.4	78.8%	95.1%	83.9%								
111	ICP-STANDARD	8-element														
112	ICP	blank			<0.017	<0.066	<0.007	<0.030								
113	TOTAL	blank(HNO3)			<0.017	<0.066	<0.007	<0.030								
114	TOTAL	8SB-HNO3			0.93	0.21	0.19	0.27								
115	TOTAL	8SB-HNO3			0.94	0.15	0.19	0.21								
116	same92#															
117	92#+standard															
118	same95#															
119	95#+standard															
120	same97#															
121	same93#															
122	same99#															
123	TOTAL	blank(HNO3)			<0.017	<0.066	<0.007	<0.030								
124	TOTAL	1PM-HNO3			1.79	34.01	22.99	30.22								
125	TOTAL	1PM-HNO3			1.65	33.08	22.58	30.51								
126	TOTAL	1PM-HNO3			93.4%	95.1%	97.5%	100.5%								
127	TOTAL	125#+standard														
128	TOTAL	3PM-HNO3			0.41	5.53	6.92	4.36								
129	TOTAL	3PM-HNO3			0.38	5.86	6.91	4.54								
130	TOTAL	3PM-HNO3+standard			88.6%	96.4%	91.5%	99.2%								
131	TOTAL	3PM-HNO3+standard			88.5%	96.7%	92.7%	98.3%								
132	TOTAL	129#+standard														
133	TOTAL	2PM-HNO3			1.57	30.14	20.88	28.02								
134	TOTAL	2PM-HNO3			1.46	28.04	19.95	27.16								
135	TOTAL	4PM-HNO3			0.35	5.39	5.47	4.98								
136	TOTAL	4PM-HNO3			0.39	5.55	5.76	5.13								
137	ICP-STANDARD	8-element-standard														
138	TOTAL	5GB-HNO3			4.69	1.38	0.10	0.03								

No.	METHOD	SAMPLE NAME	OHorpH	[OH]orpH	Cd	Pb	Cr	Ba	Ca	Al	K	Na	Si	S	Fe	Mg
			start	end	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm
139	TOTAL	5GB-HNO3			4.44	1.20	0.10	0.03								
140	TOTAL	5GB-HNO3+standard			121%	102%	93.3%	98.4%								
141	TOTAL	5GB-HNO3+standard			91.1%	93.5%	93.1%	98.2%								
142	TOTAL	6GB-HNO3			0.52	0.39	0.21	0.14								
143	TOTAL	6GB-HNO3			0.39	0.26	0.13	0.09								
144	TOTAL	143#+standard			92.1%	88.4%	88.3%	91.6%								
145	TOTAL	7SB-HNO3			0.15	0.75	0.60	1.22								
146	TOTAL	7SB-HNO3			0.15	0.79	0.58	1.15								
147	TOTAL	146#+standard			91.3%	89.3%	90.3%	94.4%								
148	ICP-STANDARD	8-element														
149	TOTAL	LiBO2-blank					2	<3								
150	TOTAL	5GB-LiBO2					4	9								
151	TOTAL	5GB-LiBO2					13	11								
152	TOTAL	7SB-LiBO2					810	887								
153	TOTAL	7SB-LiBO2					819	899								
154	TOTAL	same144#														
155	TOTAL	6GB-LiBO2					45	25								
156	TOTAL	6GB-LiBO2					35	12								
157	TOTAL	4PM-HNO3-LIBO2					6842	518								
158	TOTAL	4PM-HNO3-LIBO2					6865	508								
159	TOTAL	1PM-LiBO2					20557	3044								
160	TOTAL	1PM-LiBO2					17199	2580								
161	TOTAL	2PM-LiBO2					18470	2780								
162	TOTAL	2PM-LiBO2					18955	2672								
163	TOTAL	3PM-LiBO2					9219	478								
164	TOTAL	3PM-LiBO2					9165	455								
165	TOTAL	7SB-HNO3			14.5	85	70	121								
166	TOTAL	7SB-HNO3			15.5	69	60.35	126								
167	TOTAL	7SB-LiBO2 (after165#)					689.5	818								
168	TOTAL	7SB-LiBO2 (after166#)					726.5	804								
169	PORE SOLUTION-S	same117#														
170	TCLP	sand	4.93	4.93	<0.017	<0.066	0.008	0.06								
171	TCLP	white cement	2.88	10.45	<0.017	<0.066	<0.007	0.98								
172	STANDARD	8-element-ICP														
173	STANDARD	8-element-ICP														
174	PORE SOLUTION-E	WC-sand		0.0969	<0.17	<0.66	<0.07									
175	PORE SOLUTION-E	WC-sand		0.1182	<0.17	<0.66	<0.07									
176	PORE SOLUTION-E	WC-sand		0.0916	<0.17	<0.66	<0.07									
176A	STANDARD	8-element														
177	PORE SOLUTION-E	5GB-WC1d		0.1115	<0.17	<0.66	<0.07	1.24	431	0.66	261	2174	<1.6	5.78	<0.10	<0.14
178	PORE SOLUTION-E	5GB-HAC1d		0.5760	0.189	2.32	0.13	0.45	102	5.06	18532	2919	35.6	97.2	4.95	<0.14
179	PORE SOLUTION-E	6GB-WC1d		0.0820	<0.17	<0.66	0.07	1.34	521	0.33	101	1386	<1.6	0.63	<0.10	<0.14
180	PORE SOLUTION-E	6GB-HAC1d		0.5212	<0.17	<0.66	0.40	0.37	89.0	5.22	15918	2331	<1.6	55.3	6.58	<0.14

No.	METHOD	SAMPLE NAME	OHorpH	[OH]orpH	Cd	Pb	Cr	Ba	Ca	Al	K	Na	Si	S	Fe	Mg
			start	end	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm
181	PORE SOLUTION-E	7SB-WC1d		0.0751	<0.17	<0.66	0.36	1.81	757	0.32	246	1043	<1.6	9.24	<0.10	<0.14
182	PORE SOLUTION-E	7SB-HAC1d		0.2990	<0.17	0.78	1.50	1.07	139	3.37	10500	1586	<1.6	36.4	1.99	<0.14
183	PORE SOLUTION-E	8SB-WC1d		0.0812	<0.17	<0.66	0.08	1.29	573	0.38	217	1239	<1.6	5.36	<0.10	<0.14
184	PORE SOLUTION-E	8SB-HAC1d		0.3558	<0.17	<0.66	0.16	0.73	138	3.78	11014	1817	<1.6	21.5	2.86	<0.14
185	PORE SOLUTION-E	BLANK-WC2d(W/C=0.53)		0.0964	<0.17	<0.66	<0.07	1.06	405	0.59	311	1617	<1.6	5.67	<0.10	<0.14
186	PORE SOLUTION-E	BLANK-WC2d(W/C=0.78)		0.0795	<0.17	<0.66	<0.07	1.30	530	0.56	203	1124	<1.6	2.42	<0.10	<0.14
187	PORE SOLUTION-E	BLANK-HAC2d(W/C=0.53)		0.6160	<0.17	<0.66	0.41	0.35	69.7	6.60	19513	2502	5.25	77.3	7.72	<0.14
188-1	PORE SOLUTION-E	BLANK-HAC2d(W/C=0.78)		0.3850	<0.17	<0.66	0.18	0.44	105	4.47	12632	1575	<1.6	18.3	3.38	<0.14
188	PORE SOLUTION-E	5GB-WC28d		0.3240	0.178	<0.66	0.09	<0.3	107	4.88	599	8175	118	117	0.62	<0.14
189	PORE SOLUTION-E	5GB-HAC28d		0.8480	0.220	2.76	0.98	0.32	85.7	10.8	20815	7977	424	482	8.10	<0.14
190	TCLP	5GB-WC1d	2.84	10.50	<0.017	<0.066	<0.007	0.28								
191	TCLP	5GB-HAC1d	2.84	11.74	<0.017	<0.066	0.045	0.31								
192	TCLP	6GB-WC1d	2.87	10.05	<0.017	<0.066	0.007	0.31								
193	TCLP	6GB-HAC1d	2.87	11.70	<0.017	<0.066	0.063	0.30								
194	TCLP	7SB-WC1d	2.86	9.65	<0.017	<0.066	0.142	0.46								
195	TCLP	7SB-HAC1d	2.83	11.70	<0.017	<0.066	0.288	0.46								
196	TCLP	8SB-WC1d	2.85	10.57	<0.017	<0.066	<0.007	0.36								
197	TCLP	8SB-HAC1d	2.85	11.82	<0.017	<0.066	0.032	0.47								
198	TCLP	197+standard-ICP			91.2%	93.7%	96.4%	99.1%								
199	STANDARD	8-element														
200	TCLP	HAC	2.88	10.50	<0.007	<0.066	0.576	0.73								
201	TCLP	5GB-WC28d	2.87	10.09	<0.017	<0.066	0.016	0.34								
202	TCLP	5GB-HAC28d	2.87	11.70	<0.017	<0.066	0.024	0.42								
203	TCLP	BFS	2.91	9.47	<0.017	<0.066	<0.007	0.38								
204	STANDARD	8-element														
205	TCLP	PP-60	2.86	4.81	<0.017	<0.066	<0.007	3.04								
206	TCLP	PV														
207	PORE SOLUTION-S	PP-60-0.1M1d	0.1023	0.0956	<0.017	<0.066	<0.007	0.91								
208	PORE SOLUTION-S	BFS-0.1M1d	0.1023	0.0968	<0.017	<0.066	<0.007	0.06								
209	PORE SOLUTION-S	PP-60-1M1d	1.0235	0.9900	<0.017	<0.066	<0.007	3.72								
210	PORE SOLUTION-S	BFS-1M1d	1.0235	1.0010	<0.017	<0.066	<0.007	0.19								
211	STANDARD	8-element														
212	PORE SOLUTION-S	PP-60-1M28d	1.0128	0.9930	<0.007	<0.066	0.008	4.55								
213	PORE SOLUTION-S	BFS-1M28d	1.0128	0.9570	<0.017	<0.066	<0.007	0.19								
214	PORE SOLUTION-S	PV-1M28d														
215	PORE SOLUTION-S	PP-60-0.1M28d	0.1023	0.0912	<0.017	<0.066	<0.007	0.90								
216	PORE SOLUTION-S	BFS-0.1M28d	0.1023	0.0974	<0.017	<0.066	<0.007	0.08								
217	STANDARD	8-element														
218	PORE SOLUTION-S	Pb-sand-0.1M1d	0.1024	0.1010	<0.007	2.51	<0.007	<0.03								
219	PORE SOLUTION-S	Cr-sand-0.1M1d	0.1024	0.1011	<0.007	0.23	4.94	<0.03								
220	PORE SOLUTION-S	Pb-sand-1M1d	1.0205	1.0040	<0.007	26.98	<0.007	<0.03								
221	PORE SOLUTION-S	Cr-sand-1M1d	1.0205	1.0070	<0.007	0.23	3.65	<0.03								
222	STANDARD	8-element														

No.	METHOD	SAMPLE NAME	OHorpH	[OH]orpH	Cd	Pb	Cr	Ba	Ca	Al	K	Na	Si	S	Fe	Mg
			start	end	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm
223	PORE SOLUTION-S	Cu2O-sand-0.1M1d	0.1021	0.0996	<0.017	<0.066	<0.007	Cu1.63								
224	PORE SOLUTION-S	Cd-sand-0.1M1d	0.1021	0.0995	0.028	<0.066	<0.007	<0.03								
225	PORE SOLUTION-S	Cu2O-sand-1M1d	1.0034	1.0041	<0.017	<0.066	<0.007	Cu8.67								
226	PORE SOLUTION-S	Cd-sand-1M1d	1.0034	1.0041	0.265	0.068	<0.007	<0.03								
227	PORE SOLUTION-E	1PM-WC-1d		0.0160	0.37	14.9	652	0.58	4820	1.88	212	236	20.6	329	1.56	<0.14
228	PORE SOLUTION-E	1PM-WC-BFS-1d		0.0070	<0.17	6.9	227	1.08	2600	13.9	345	371	17.5	49.7	1.96	<0.14
229	PORE SOLUTION-E	1PM-HAC-1d		0.0188	<0.17	7.7	1310	0.32	1700	0.54	6560	848	21.3	1160	1.19	<0.14
230	PORE SOLUTION-E	1PM-HAC-BFS-1d		0.0158	<0.17	<0.66	1210	<0.30	3080	0.65	4980	720	25.0	1380	0.55	<0.14
231	PORE SOLUTION-E	2PM-WC-1d		0.0178	0.30	16.4	612	0.83	4350	1.94	380	353	24.9	66.1	0.84	<0.14
232	PORE SOLUTION-E	2PM-WC-BFS-1d		0.0100	0.21	<0.66	185	1.27	2490	18.2	379	395	19.4	50.7	3.44	<0.14
233	PORE SOLUTION-E	2PM-HAC-1d		0.0200	<0.17	7.5	1330	<0.30	1950	0.67	6760	879	23.5	1270	0.96	<0.14
234	PORE SOLUTION-E	2PM-HAC-BFS-1d		0.0171	<0.17	<0.66	1210	<0.30	2760	0.57	4970	725	23.0	1340	0.45	<0.14
235	PORE SOLUTION-E	3PM-WC-1d		0.0728	<0.17	<0.66	21.5	2.85	987	<0.17	259	714	10.7	57.7	<0.10	<0.14
236	PORE SOLUTION-E	3PM-WC-BFS-1d		0.0688	<0.17	<0.66	20.9	2.59	1390	<0.17	239	546	13.4	43.2	<0.10	<0.14
237	PORE SOLUTION-E	3PM-HAC-1d		0.2390	<0.17	<0.66	155	2.14	173	0.84	13980	1640	22.8	467	0.46	<0.14
238	PORE SOLUTION-E	3PM-HAC-BFS-1d		0.1550	<0.17	<0.66	144	1.93	260	0.25	9230	1140	21.6	311	0.17	<0.14
239	PORE SOLUTION-E	4PM-WC-1d		0.0610	<0.17	<0.66	11.8	3.27	1120	0.20	310	709	8.87	32.5	<0.10	<0.14
240	PORE SOLUTION-E	4PM-WC-BFS-1d		0.0460	<0.17	<0.66	23.3	3.82	939	<0.17	292	627	9.40	49.6	<0.10	<0.14
241	PORE SOLUTION-E	4PM-HAC-1d		0.2900	<0.17	<0.66	87.5	1.32	247	1.55	14070	1630	20.3	275	0.84	<0.14
242	PORE SOLUTION-E	4PM-HAC-BFS-1d		0.2080	<0.17	<0.66	76.6	1.70	333	1.06	10200	1270	16.7	161	0.47	<0.14
243	PORE SOLUTION-S	Pb-sand-0.1M28d	0.1024	0.1009	<0.17	3.90	<0.007	<0.03								
244	PORE SOLUTION-S	Cr-sand-0.1M28d	0.1024	0.1007	<0.17	0.13	4.11	<0.03								
245	PORE SOLUTION-S	Pb-sand-1M28d	1.0207	1.0117	<0.17	26.94	<0.007	<0.03								
246	PORE SOLUTION-S	Cr-sand-1M28d	1.0207	1.0117	<0.17	0.21	2.96	<0.03								
247	PORE SOLUTION-E	5GB-WC-1d		0.0824	<0.17	<0.66	0.15	0.98	247	<0.17	175	1879	14.3	10.9	<0.10	<0.14
248	PORE SOLUTION-E	5GB-HAC-1d		0.5078	<0.17	2.96	0.28	0.58	119	5.70	17059	2683	50.2	61.1	3.99	<0.14
249	PORE SOLUTION-E	6GB-WC1d		0.0766	<0.17	<0.66	0.17	2.01	645	0.65	81.5	1242	7.83	<1.9	<0.10	<0.14
250	PORE SOLUTION-E	6GB-HAC-1d		0.4560	<0.17	<0.66	1.40	0.50	117	4.49	15963	2130	16.5	49.7	4.71	<0.14
251	PORE SOLUTION-E	1PM-WC-28d		0.0180	0.30	18.1	333	1.05	6400	1.63	479	479	68.6	61.0	0.96	<0.14
252	PORE SOLUTION-E	1PM-WC-BFS-28d		0.0175	0.29	11.5	459	0.72	6700	1.11	453	427	70.2	128	0.67	<0.14
253	PORE SOLUTION-E	1PM-HAC-28d		0.0242	<0.17	8.46	1080	0.45	5680	1.10	7080	910	83.9	802	2.25	0.56
254	PORE SOLUTION-E	1PM-HAC-BFS-28d		0.0227	<0.17	5.90	1040	0.31	6590	0.59	5190	739	79.6	950	1.23	0.22
255	PORE SOLUTION-E	2PM-WC-28d		0.0196	0.29	19.0	263	1.18	6060	1.38	474	468	71.9	62.3	0.88	<0.14
256	PORE SOLUTION-S	Cr-BFS-0.1M1d	0.1024	0.0975	<0.017	0.10	4.33	<0.03								
257	PORE SOLUTION-S	Cr-BFS-1M1d	1.0163	0.9975	<0.017	<0.066	3.35	0.13								
258	PORE SOLUTION-E	2PM-WC-BFS-28d		0.0194	<0.17	13.8	456	0.77	7030	1.21	461	474	75.7	142	0.77	<0.14
259	PORE SOLUTION-E	2PM-HAC-28d		0.0252	<0.17	8.33	1040	0.40	5660	0.76	6830	872	80.7	864	2.07	0.30
260	PORE SOLUTION-E	2PM-HAC-BFS-28d		0.0231	<0.17	6.94	1030	0.38	6760	0.77	5180	757	81.6	922	1.51	0.38
261	PORE SOLUTION-E	3PM-WC-28d		0.0921	0.37	1.71	0.40		15.0	0.30	<15.8	15.7	2.57	<1.9	0.70	7.56
262	PORE SOLUTION-E	3PM-WC-BFS-28d		0.0885	<0.17	<0.66	2.32	2.58	696	0.54	1377	2534	30.0	250	0.47	<0.14
263	PORE SOLUTION-E	2PM-WC-HighBFS-1d		0.0131	<0.17	2.46	770	0.45	3759	0.55	213	273	17.6	354	0.11	0.70
264	PORE SOLUTION-E	2PM-HAC-HighBFS-1d		0.0131	<0.17	2.32	845	0.19	3797	0.44	1254	402	19.4	770	0.17	0.80
265	PORE SOLUTION-E	3PM-HAC-28d		0.9572	<0.17	7.57	49.5	3.16	124	6.04	46030	8137	132	327	5.06	<0.14

No.	METHOD	SAMPLE NAME	OHorpH start	[OH]orpH end	Cd ppm	Pb ppm	Cr ppm	Ba ppm	Ca ppm	Al ppm	K ppm	Na ppm	Si ppm	S ppm	Fe ppm	Mg ppm
266	PORE SOLUTION-E	3PM-HAC-BFS-28d		0.5486	<0.17	1.18	9.22	3.86	176	5.14	25595	5649	85.4	427	2.92	<0.14
267	PORE SOLUTION-E	4PM-WC-28d		0.0773	<0.17	<0.66	5.26	2.38	812	0.34	786	2511	26.3	38.9	<0.10	<0.14
268	PORE SOLUTION-E	4PM-WC-BFS-28d		0.1214	<0.17	<0.66	3.02	8.51	692	0.71	2849	4859	44.1	472	<0.10	<0.14
269	PORE SOLUTION-E	4PM-HAC-28d		0.6730	<0.17	4.25	30.61	2.71	121	4.26	33414	5994	92.4	248	2.81	<0.14
270	PORE SOLUTION-E	4PM-HAC-BFS-28d		0.4578	<0.17	0.91	8.37	2.63	175	4.14	21161	4478	62.6	375	1.74	<0.14
271	PORE SOLUTION-S	Cd-sand-0.1M28d	0.1024	0.0998	0.037	<0.066	0.084	<0.03								
272	PORE SOLUTION-S	Cu2O-sand-0.1M28d	0.1024	0.1002	<0.017	<0.066	0.014	Cu0.33								
273	TCLP	2PM-WC-BFS-28d-NOT-E	2.92	0.0234	<0.017	0.33	15.99	0.47	2913	0.19	13.09	17.87	1.70	78.6	0.01	0.08
274	TCLP	2PM-HAC-BFS-28d-NOT-E	2.92	0.0094	<0.017	0.079	19.42	0.40	2480	0.28	118.1	24.58	3.72	154	0.03	0.19
275	PORE SOLUTION-E	5GB-WC-28d		0.2520	<0.17	<0.66	0.25	0.40	141	1.49	521	6549	116	67.9	0.22	<0.14
276	PORE SOLUTION-E	5GB-HAC-28d		0.8620	<0.17	3.15	1.02	0.46	67.3	9.26	23862	7115	480	244	4.79	<0.14
277	PORE SOLUTION-E	6GB-WC-28d		0.1916	<0.17	<0.66	0.13	0.65	215	1.13	438	4227	41.2	20.8	<0.10	<0.14
278	PORE SOLUTION-E	6GB-HAC-28d		0.7745	<0.17	<0.66	1.09	0.48	58.3	8.55	23049	4783	28.2	162	7.20	<0.14
279	PORE SOLUTION-S	Cd-sand-1M28d	1.0035	1.0079	0.347	<0.006	<0.007	<0.03								
280	PORE SOLUTION-S	Cu2O-sand-1M28d	1.0035	1.0022	<0.017	<0.066	0.011	Cu32.15								
281	TCLP	Cr-BFS	2.86	9.49	<0.017	<0.066	<0.007	0.33								
282	TCLP	Pb-BFS	2.86	9.48	<0.017	<0.066	<0.007	0.32								
283	PORE SOLUTION-S	Cr(metal)-0.01M1d					0.009									
284	PORE SOLUTION-S	Cr(metal)-0.1M1d					<0.007									
285	PORE SOLUTION-S	Cr(metal)-1M1d					<0.007									
286	PORE SOLUTION-S	Pb-BFS-0.1M1d	0.1021	0.0994	<0.017	<0.066	<0.007	0.06								
287	PORE SOLUTION-S	Pb-BFS-1M1d	1.0213	1.0041	<0.017	<0.066	<0.007	0.14								
288	PORE SOLUTION-E	2PM-WC-HighBFS-28d		0.0155	0.09	2.50	959	0.46	8950	1.7	448	355	262	451	0.20	1.3
289	PORE SOLUTION-E	2PM-HAC-HighBFS-28d		0.0134	0.04	1.71	960	0.34	8940	1.3	1609	471	148	814	0.40	2.1
290	TCLP	2PM-WC-HighBFS-1d	2.91	0.0012	<0.017	<0.066	9.73	0.38	1942	0.15	15.23	14.03	15.88	67.65	0.01	52.21
291	TCLP	2PM-HAC-HighBFS-1d	2.91	0.0012	<0.017	<0.066	8.38	0.41	2082	0.14	29.74	15.67	12.86	75.74	<0.01	72.59
292	TCLP	2PM-WC-28d-NOT-E	2.91	0.0278	<0.017	0.29	16.11	0.43	2623	0.29	12.08	19.12	3.43	88.1	0.01	0.07
293	TCLP	2PM-HAC-28d-NOT-E	2.91	0.0141	<0.017	0.08	15.32	0.36	2452	0.29	166.2	27.54	5.28	177.2	0.01	0.14
294	TCLP	2PM-WC-28d	2.91	0.0195	<0.017	0.19	24.84	0.37	2432	0.46	4.92	10.89	3.33	84.7	<0.01	0.06
295	TCLP	2PM-WC-BFS-28d	2.91	0.0160	<0.017	0.14	17.98	0.39	2347	0.44	6.58	11.45	2.81	82.6	<0.01	0.07
296	TCLP	2PM-HAC-28d	2.91	0.0210	<0.017	0.16	10.80	0.52	2408	0.20	59.55	14.81	3.31	93.93	<0.01	0.06
297	TCLP	2PM-HAC-BFS-28d	2.91	0.0110	<0.017	0.08	9.00	0.39	2291	0.73	40.35	12.56	4.10	140.5	<0.01	0.09
298	PORE SOLUTION-S	Cr-BFS-0.1M28d	0.1017	0.0969	<0.017	<0.066	2.42	0.07								
299	PORE SOLUTION-S	Cr-BFS-1M28d	1.0171	0.9984	<0.017	<0.066	2.65	0.15								
300	TCLP	2PM-WC-HighBFS-28d	2.91	0.0009	<0.017	<0.066	5.89	0.39	1945	0.12	14.12	14.85	13.97	67.51	0.02	83.15
301	TCLP	2PM-HAC-HighBFS-28d	2.91	0.0009	<0.017	<0.066	6.28	0.40	1848	0.13	23.71	13.61	16.37	74.39	0.02	175.2
302	TCLP	1PM-WC-28d	2.91	0.0188	<0.017	0.18	23.83	0.32	2486	0.53	4.54	8.56	3.00	95.30	<0.01	0.58
303	TCLP	1PM-HAC-28d	2.91	0.0163	<0.017	0.13	9.87	0.38	2450	0.19	52.37	11.13	4.00	151.2	<0.01	0.26
304	TCLP	1PM-WC-BFS-28d	2.89	0.0158	<0.017	0.14	17.38	0.36	2385	0.52	6.39	10.31	3.35	90.31	0.01	0.19
305	TCLP	1PM-HAC-BFS-28d	2.89	0.0059	<0.017	<0.066	7.72	0.36	2240	0.39	47.11	12.27	6.87	156.0	0.01	0.59
306	PORE SOLUTION-S	Pb-BFS-0.1M28d	0.1021	0.0978	<0.017	0.098	<0.007	0.07								
307	PORE SOLUTION-S	Pb-BFS-1M28d	1.0213	0.9998	<0.017	<0.066	<0.007	0.15								
308	TCLP	0.1%ZnCrO4-BFS(MIX)	2.91	9.50			<0.007									

No.	METHOD	SAMPLE NAME	OHorpH	[OH]orpH	Cd	Pb	Cr	Ba	Ca	Al	K	Na	Si	S	Fe	Mg
			start	end	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm
309	TCLP	1%ZnCrO4-BFS	2.91	9.46			3.41									
310	TCLP	2%ZnCrO4-BFS(MIX)	2.91	9.50			0.66									
311	TCLP	2PM-WC-1d	2.90	0.0261	<0.017	0.42	20.47	0.51	2607	0.38	19.07	17.84	9.01	99.18	<0.01	0.10
312	TCLP	2PM-HAC-1d	2.90	0.0207	<0.017	0.25	14.96	0.53	2491	0.30	74.23	18.66	9.31	120.4	<0.01	0.10
313	TCLP	2PM-WC-BFS-1d	2.90	0.0175	<0.017	0.19	16.92	0.43	2307	0.58	14.74	14.74	3.73	89.55	<0.01	0.10
314	TCLP	2PM-HAC-BFS-1d	2.90	0.0097	<0.017	0.14	11.94	0.41	2318	0.76	56.29	16.60	4.51	164.1	<0.01	0.10
315	Cr-standard-BFS	Cr-standard-BFS					23.16									
316	TCLP	Cd-sand	4.92	4.97	52.18	<0.066	<0.007	<0.03								
317	TCLP	Cu2O-sand	4.89	4.91	0.021	<0.066	<0.007	Cu23.53								
318	TCLP	1%ZnCrO4-BFS(MIX)	2.91	9.44			0.011									
319	TCLP	1PM-WC-NOT-E	2.90	0.0246	<0.017	0.255	22.72	0.39	2579	0.36	11.55	17.43	13.71	73.26	0.01	0.41
320	TCLP	1PM-HAC-NOT-E	2.90	0.0118	<0.017	<0.066	15.07	0.37	2389	0.42	158.6	25.20	11.39	159.5	0.01	0.20
321	TCLP	1PM-WC-BFS-NOT-E	2.91	0.0179	<0.017	0.162	15.94	0.39	2444	0.43	13.09	17.14	6.84	83.4	0.01	0.10
322	TCLP	1PM-HAC-BFS-NOT-E	2.91	0.0072	<0.017	<0.066	16.54	0.37	2364	0.60	127.8	24.02	31.75	172.2	0.02	0.20
323	TCLP	1PM-WC-1d	2.92	0.0239	<0.017	0.296	19.11	0.43	2472	0.35	9.59	14.47	2.90	83.20	<0.01	0.10
324	TCLP	1PM-HAC-1d	2.92	0.0174	<0.017	0.142	18.81	0.41	2399	0.18	113.6	20.08	3.76	158.0	<0.01	0.10
325	TCLP	1PM-WC-BFS-1d	2.92	0.0164	<0.017	0.168	15.51	0.37	2325	0.54	10.00	13.98	2.56	85.54	<0.01	0.10
326	TCLP	1PM-HAC-BFS-1d	2.91	0.0082	<0.017	0.066	16.00	0.37	2270	0.52	91.55	18.79	4.68	168.9	0.01	0.20
327	PORE SOLUTION-E	RRAD PERMAFIX D 7d		0.0062	<0.17	0.09	0.10	0.35	676	71.6	5788	12624	19.8	10144	3.3	2.0
328	TCLP	RRAD PERMAFIX D 7d	2.92	6.49	0.030	<0.066	0.052	0.38	2251	5.54	42.93	66.97	22.65	774.4	84.35	68.18
329	PORE SOLUTION-E	RRAD PERMAFIX C 28d		0.0063	<0.17	0.15	0.23	0.30	732	70.6	5079	11981	75.0	7384	2.8	7.0

Abbreviations and Acronyms

amu	atomic mass unit
CFC	chlorofluorocarbon
CTX	Center for Technical Excellence
DESCOM	U.S. Army Depot Systems Command
DI	deionized
EI	electron impact
EDTA	ethylenediaminetetraacetic acid
EPA	U.S. Environmental Protection Agency
GC/MS	gas chromatography/mass spectroscopy
HCN	hydrogen cyanide
ID	inside diameter
$LiBO_2$	lithium metaborate
LTA	low-temperature ashing
M	molar concentration
MPa	megapascals
MSDS	Material Safety Data Sheet
m/z	mass/atomic number
OD	outside diameter
ORNL	Oak Ridge National Laboratory
PMB	plastic media blasting
RCRA	Resource Conservation and Recovery Act
RRAD	Red River Army Depot
TCLP	Toxicity Characteristic Leaching Procedure
TD	thermal desorption
TG	thermogravimetric (analysis)
TST	triple sorbent trap
USACERL	U.S. Army Construction Engineering Research Laboratories
USAEC	U.S. Army Environmental Center
VOC	volatile organic compound

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Technical Memorandum
TM-2178-ENV

RECYCLING AND REUSE OPTIONS FOR SPENT ABRASIVE BLASTING MEDIA AND SIMILAR WASTES

by

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This handbook is designed to help Navy personnel with waste minimization and pollution prevention efforts by assisting them to identify and apply recycling and resuse options for mineral-based spent abrasive blasting media (ABM) and similar waste materials. The handbook is intended as a technology transfer document to increase the awareness of recycling and reuse options for spent ABM and similar wastes. The following types of information will be included in the handbook: (1) defining the contaminant and matrix characteristics for ABM and similar wastes, (2) outlining specific technologies for recycling and reusing these wastes, and (3) describing how to identify and evaluate options for recycling and reusing these wastes.

Recycling spent ABM has the potential to significantly reduce waste generation while saving money. The reported production rate of spent ABM from eight U.S. Navy shipyards is in the range of 75,000 to 100,000 tons (68,000 to 90,800 metric tons) per year (Bryan et al., 1990). Promising waste minimization alternatives are available for managing ABM.

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ACRONYMS AND ABBREVIATIONS

AASHTO	American Association of State Highway and Transportation Officials
ABM	abrasive blasting media
ARRA	Asphalt Recycling and Reclaiming Association
ASTM	American Society for Testing and Materials
BDAT	Best Demonstrated Available Technology
BDL	below detection limit
Caltrans	California Department of Transportation
C&D	construction and demolition
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	*Code of Federal Regulations*
DNR	Department of Natural Resources
DTSC	(California) Department of Toxic Substances Control
EAF	electric arc furnace
EPA	Environmental Protection Agency
FIFRA	Federal Insecticide, Fungicide, and Rodenticide Act
FOB	free on board
FR	*Federal Register*
IGT	Institute of Gas Technology
MTPY	metric tons per year
NFESC	Naval Facilities Engineering Service Center
OAR	Oregon Administrative Rules
OMB	Office of Management and Budget
PCB	polychlorinated biphenyl
ppm	parts per million
R&D	research and development
RCRA	Resource Conservation and Recovery Act
SIC	Standard Industrial Classification
SITE	Superfund Innovative Technology Evaluation
SSPC	Steel Structures Painting Council
STLC	(California) Soluble Threshold Limit Concentration
TCLP	Toxicity Characteristic Leaching Procedure
TIM	(Washington Department of Ecology) Technical Information Memorandum
UCD	use constituting disposal

VISITT	Vendor Information System for Innovative Treatment Technologies
WAC	Washington Administrative Code
WET	(California) Waste Extraction Test

RECYCLING AND REUSE OPTIONS FOR SPENT ABRASIVE BLASTING MEDIA AND SIMILAR WASTES

1.0 INTRODUCTION

This handbook is designed to help Navy personnel with waste minimization and pollution prevention efforts by assisting them to identify and apply recycling and reuse options for mineral-based spent abrasive blasting media (ABM) and similar waste materials. The handbook is intended as a technology transfer document to increase the awareness of recycling and reuse options for spent ABM and similar wastes. The following types of information will be included in the handbook:

- defining the contaminant and matrix characteristics for ABM and similar wastes
- outlining specific technologies for recycling and reusing these wastes
- describing how to identify and evaluate options for recycling and reusing these wastes.

The handbook does not address steel shot, glass beads, plastic beads, sodium bicarbonate, or wheat starch ABM.

Recycling spent ABM has the potential to significantly reduce waste generation while saving money. The reported production rate of spent ABM from eight U.S. Navy shipyards is in the range of 75,000 to 100,000 tons (68,000 to 90,800 metric tons) per year (Bryan et al., 1990). Promising waste minimization alternatives are available for managing ABM.

Specific processes and vendors are mentioned in many sections of this technology transfer report. Mention of a process or a vendor does not constitute a recommendation or endorsement. All descriptions and data are taken from literature data. None of the reported results are based on data collected by or first-hand knowledge of the authors.

2.0 WASTE CHARACTERISTICS

This section describes the physical properties and chemical composition of slag and mineral ABM and the contaminant content of spent ABM and similar wastes.

2.1 Characteristics of Abrasive Blasting Media

This section describes the types of ABM used to remove paint from ships, bridges, and similar large structures documents the physical and chemical characteristics of the ABM.

2.1.1 Types of Abrasive Blasting Media used at Shipyards

Many types of ABM are used to remove paint, coatings, and/or corrosion from industrial structures. Any ABM used at a U.S. Navy shipyard or at a private shipyard working on U.S. Navy vessels must meet Mil-A-22262b(SH) specifications. The qualified ABM are listed in Appendix A. Processed coal and metallurgical slags are popular sources for ABM, but natural mineral materials may also be used. Slag blasting media are typically used once in a blasting operation and then discarded, although tougher materials such as garnet can be cleaned and reused.

One widely used type of ABM is made as a byproduct of coal combustion. The ABM is a fused ferro-alumino-silicate formed when molten slag from a coal combustion boiler is quenched in water. The water quench cools the slag quickly, resulting in an amorphous, noncrystalline particulate. Thermal shock from the rapid cooling fractures the slag into rough, angular particles. ABM can be produced from the slag particles simply by segregating different particle-size grades using screens (Austin, 1995). Higher quality ABM can be made by performing an initial crushing and screening followed by magnetic separation to remove metal particles. The upgraded slag particulate is then screened to separate size grades. The 11 companies that supply ABM made from coal slag had total volume and sales in 1992 of 442,000 tons (401,000 metric tons) and $19,500,000, respectively. Reed Minerals, the largest volume producer supplying about 62% of the sales, makes a product called Black Beauty™ (the use of trade names in this report does not necessarily constitute endorsement for use). Due to the dominance of the Black Beauty™ in the coal slag ABM market, many users incorrectly use the trade name as a generic term for coal slag ABM. Similar materials made by the other companies are marketed under other trade names such as Stan-Blast™ made by Stan-Blast Abrasives (17% of sales) and Black Diamond™ made by Foster Dixianan (10% of sales) (Paumanok, 1992).

ABM is also made from slag produced by pyrometallurgical processing to recover copper or nickel. The metallurgical slags are quenched to produce glassy fragments and then screened in the same manner as the coal slag. As with the coal slag, magnetic separation may be used to remove metal particles.

Copper slag is a mixture of ferrosilicate, ferro-alumino silicate, calcium silicate, magnesium silicate, and silica with trace amounts of antimony, arsenic, copper, and lead. Seven companies supply ABM made from copper slag with total volume and sales in 1992 of 187,000 tons (170,000 metric tons) and $10,300,000, respectively. The largest suppliers are Kleen-Blast Abrasives (37% of sales volume), Minerals Research and Recovery (29% of sales volume), RDM Multi-Enterprises (21% of sales volume), and MDC Industries (7.5% of sales volume) (Paumanok, 1992). The copper slag materials are marketed under trade names such as Sharp Shot™, Apache Black Hawk™, and Copper Blast™. The copper slag ABM product trade-named Kleen Blast™ is imported from Canada.

Nickel slag is a mixture of magnesium ferro-silicate and silica with trace amounts of other metals (Austin, 1995). There are two suppliers of nickel slag ABM in the United States market. Green Diamond Abrasives produces Green Diamond™ nickel slag using slag from a smelter near Riddle, Oregon, with total volume and sales in 1992 of 45,000 tons (40,800 metric tons) and $3,200,000, respectively. Kayway Industries imports about 5,000 tons/yr (4,540 metric tons/yr) of nickel slag ABM from Canada for sale in the United States (Paumanok, 1992).

Physical and chemical characteristics influence the recyclability of slag ABM. The regulatory status is the single most important factor because waste management practices controlled by the Resource Conservation and Recovery Act (RCRA) or state hazardous waste regulations reduce the flexibility in selecting and implementing recycling options. Physical properties such as particle size and shape and chemical properties such as total composition also affect the acceptance of spent ABM in commercial applications.

ABM produced from slag may contain elevated background levels of regulated metals. ABM from coal slag will typically contain nickel and vanadium and a variety of other metals depending on the coal that was used as the source of the slag. Copper slag from primary smelters contains elevated copper and barium levels and lower but significant levels of cobalt, trivalent chromium, and nickel. Copper slag from secondary smelters may contain significant levels of lead and arsenic. Nickel slag typically contains elevated concentrations of nickel, copper, and trivalent chromium and lower levels of cobalt and vanadium. Arsenic, barium, cadmium, chromium, lead, mercury, selenium, and silver are used to determine leachable metal toxicity by the U.S. Environmental Protection Agency (U.S. EPA) under RCRA. Some states, for example California, consider additional metals and total content as well as leachability in their definition of hazardous waste. It is unlikely but possible that unused ABM will be classified as a hazardous material by virtue of its background soluble or total metal content. A high background metals content in the virgin ABM means that the addition of a relatively small amount of metals-containing dust during blasting may cause the spent ABM to be classified as hazardous.

Most ABM are produced in at least three different particle size grades. In general, the coarser grades are more compatible with recycling as aggregate for portland cement concrete or asphaltic concrete because they mix better. Rounded particles are more suitable for use in portland cement, whereas sharp, angular particles are better for use in asphaltic concrete.

The chemical composition can affect the performance of spent ABM. The dark colors of slag ABM may limit acceptance in products with an appearance function where the slag materials replace lighter colored natural minerals. High chloride concentrations are undesirable in many applications. Sulfate concentrations or high alkali reactivity would make the ABM unsuitable for use as aggregate in portland cement.

Natural minerals such as silica sand, garnet, or staurolite are also used for ABM. Silica sand ABM is typically composed of mostly quartz with some garnet and feldspar and traces of lithic fragments such as hornblende. The fine silica particles produced by blasting with sand create a significant health concern, so use of sand as ABM is declining. Garnet is a general name for a family of complex silicate minerals having similar physical properties and crystal form. The general formula for garnet is $A_3B_2(SiO_4)_3$, where A can be calcium, magnesium, ferrous iron, or manganese and B can be aluminum, ferric iron, chromium, or (in rare cases) titanium. The most common garnet minerals for use as ABM are $Mg_3Al_2(SiO_4)_3$ (pyrope), $Fe_3Al_2(SiO_4)_3$ (almandite), and $Ca_3Fe_2(SiO_4)_3$ (andradite). Almandite and almandite-pyrope solid solutions make the best abrasive grains. Andradite is softer and breaks down more easily. Staurolite is $(Fe^{2+},Mg,Zn)_2Al_9(Si,Al)_4O_{23}(OH)_2$.

Mineral ABM may be naturally occurring sand or may be manufactured by crushing and size-grading using screens. Sand for abrasive blasting is produced by 48 companies operating 84 mines (Austin, 1995). Silica sand does not meet the requirements of the MIL-A-22262b(SH) specification due to the high free silica content. Ten firms produce garnet ABM with a total volume and sales in 1992 of 25,000 tons (22,700 metric tons) and $7,800,000, respectively (Paumanok, 1992). DuPont, marketing Starblast™, is the only supplier of staurolite ABM. Unofficial sources estimate the 1992 volume and sales for Starblast™ at 55,000 tons (50,000 metric tons) and $7,700,000, respectively (Paumanok, 1992). Similar to slag ABM, mineral ABM is available in different particle sizes, with the coarse grades more amenable to recycling into asphalt. However, unlike slag ABM, abrasives made from natural minerals contain low background metals concentrations. The matrix of mineral ABM is unlikely to contribute to total or leachable hazardous metals which can make recycling easier.

2.1.2 Physical Characteristics of Abrasive Blasting Media

As discussed above, the physical properties of ABM influence the selection of recycling options. Some key properties of unused slag and mineral ABM are shown in Table 2-1.

Table 2-1. Physical Properties of Unused Abrasive Blasting Media

Parameter	Coal Slag ABM Properties	Copper or Nickel Slag ABM Properties	Silica Sand ABM Properties	Garnet ABM Properties
Physical form	Angular, amorphous grains	Angular, amorphous grains	Rounded irregular, crystalline grains	Subangular, crystalline grains
Mesh sizes available (U.S. screen size)	10 to 100	8 to 80	6 to 270	8 to 300
CAS[(a)] number	68476-96-0	No data	No data	1302-62-1
Melting point (°F)	>2,000	2,400	No data	>2,280
Hardness (Mohs scale)	6 to 7.5	7 to 7.5	5 to 6	6.5 to 9
Bulk density lb/ft^3	75 to 100	84 to 95	100	130 to 147
Specific gravity	2.8	2.8 to 3.6	2.6	3.2 to 4.3
Water solubility	Negligible	Negligible	Negligible	Negligible
Color	Black	Black	White to tan	Wide variation, generally red to brown

(a) CAS is Chemical Abstracts Service.
Source: Compiled from Austin, 1995; Williams, 1991; and manufacturers' literature.

ABM is available in grades, based on particle size, ranging from extra coarse to very fine. The size grading available varies with the grit maker but some example particle size ranges for grades of expendable ABM are indicated in Table 2-2. The correspondence of screen size to screen opening is shown in Table 2-3 along with the Unified Soil Classification size ranges for sand, silt, and clay to provide a basis for comparing the size of ABM with typical soil materials.

Table 2-2. Example Screen Size Ranges for Abrasive Blasting Media[a]

U.S. Screen Size	Coarse (4.0 to 5.5 mil)[b]	Medium (3.0 to 4.0 mil)[b]	Fine (2.0 to 3.5 mil)[b]
6	0	0	0
8	5	0	0
12	25	3	0
16	33	37	0.4
20	17	28	11
30	12	19	43
40	6	9.2	34
50	1.5	3.1	8.5
pan	0.5	0.7	2.9

(a) Percent of sample retained on screen.
(b) Anchor pattern given by grade of grit.

2.1.3 Chemical Characteristics of Abrasive Blasting Media

This section summarizes some recent data about the total composition and leachable metals content of unused and spent ABM. As discussed in Section 2.1.1, slag media may contain elevated levels of regulated metals. Pigments in paint chips removed by ABM increase the leachable metal content of spent ABM. Some common pigments containing RCRA hazardous metals include red lead, white lead, chromium yellow, chromium orange, molybdate orange, zinc yellow, chromium green, and chromium oxide green (U.S. EPA, 1990b, EPA/530-SW-90-059Y). Spent ABM in shipyards can contain paint chips with copper- or tributyltin-based antifouling paints or lead-based primers.

2.1.3.1 Chemical Characteristics of Unused Media. The approximate chemical composition of some example slag and mineral ABM materials in unused condition is shown in Table 2-4. Most coal slag ABM contains only small quantities of RCRA-regulated metals, and the vitrified form provides a leach-resistant matrix, so hazardous metal leachability should be low. For example, all Toxicity Characteristic Leaching Procedure (TCLP) leachable metal concentrations from Black Beauty™ ABM, as shown in Table 2-5, are far below the regulatory level for a toxic leachable characteristic. Metallurgical slag typically will have higher residual metal content but is still unlikely to have a RCRA leachable toxicity characteristic in the unused condition. The natural mineral ABM materials should have low trace metal content (see Table 2-5). The Mil Spec for ABM requires that unused material pass both the RCRA and the California leaching tests.

2.1.3.2 Chemical Characteristics of Media Used on Ships. Mare Island Naval Shipyard in Vallejo, California generated about 2,000 tons (1,800 metric tons) per year of spent ABM from sandblasting submarines. Mare Island used ABM derived from a slag copper smelting that is sold under the trade name of Kleen Blast™. The average bulk elemental composition of Kleen Blast™ is as follows:

Iron oxide as Fe_2O_3	23%
Silica as SiO_2	45%
Alumina as Al_2O_3	7%
Calcium as CaO	19%
Sodium as Na_2O	<0.2%
Potassium as K_2O	<0.1%
Magnesium as MgO	6%

Table 2-3. Correspondence of Screen Size Number to Opening Size

U.S. Screen Size	Opening Size (mm)	Opening Size (inches)	Unified Soil Classification
4	4.75	0.187	Coarse sand
6	3.35	0.132	
8	2.36	0.0937	
10	2.00	0.0787	
12	1.7	0.0661	Medium sand
14	1.4	0.0555	
16	1.18	0.0469	
18	1.00	0.0394	
20	0.850	0.0331	
30	0.600	0.0234	
40	0.425	0.0165	
50	0.300	0.0117	
60	0.250	0.0098	
70	0.212	0.0083	Fine sand
80	0.180	0.0070	
100	0.150	0.0059	
120	0.125	0.0049	
140	0.106	0.0041	
200	0.075	0.0029	
230	0.063	0.0025	Clay or silt(a)
270	0.053	0.0021	
325	0.045	0.0017	

(a) Clay is soil passing a 0.003-in (0.075-mm) screen that is plastic (putty-like) and has strength after drying in the air, and silt is soil passing a 0.003-in (0.075-mm) screen that shows little or no plasticity and has no strength when dried in the air.

Source: ASTM, 1995, Specification E 11 and Standard D 2487.

The total copper content of Kleen Blast™ is about 0.2%. Copper or tributyltin from antifouling paints and lead and other metals from paint pigments may increase the metal loading in the ABM during sandblasting. The types and concentrations of metals depend on the types of paints and coatings being removed. Typical metals concentrations in the spent ABM at Mare Island are shown below:

	mg/kg		mg/kg
Copper (Cu)	3,120	Cobalt (Co)	70
Barium (Ba)	1,080	Nickel (Ni)	62
Zinc (Zn)	197	Lead (Pb)	33
Vanadium (V)	118	Arsenic (As)	25
Chromium (Cr)	90		

Table 2-4. Chemical Composition of Unused Abrasive Blasting Media

Component	Coal Slag ABM Comp. (weight %)	Copper Slag ABM Comp. (weight %)	Silica Sand ABM Comp. (weight %)	Garnet ABM Comp. (weight %)
SiO_2	47.2	32 to 45	>99	36 to 37
Free SiO_2	<1	<1	>99	<1
Al_2O_3	21.4	3.0 to 7.0	0.15	20
FeO				30
Fe_2O_3	19.2	23 to 48	0.045	2 to 33
CaO	6.8	0 to 19	0.011	1 to 2
MgO	1.5	1.5 to 6.0	0.005	3 to 6
K_2O	1.6	<0.1 to 1.2		
TiO_2	1.0		0.013	2
Na_2O	0.6	<0.2		
MnO				1
As	<0.0001	0.01 to 0.04		<0.01
Co	0.00023	0.02 to 0.03		<0.01
Cr	0.00013	0.04 to 0.05		<0.01
Cu	0.00046	0.2 to 0.4		<0.01
Pb	0.00014	0.1 to 0.2		<0.01

Source: Compiled from Austin, 1995; Williams, 1991; and manufacturers' literature.

Table 2-5. Toxicity Characteristic Leaching Procedure Analysis Results for Unused Abrasives

Contaminant	Coal Slag Leachability[(a)] (mg/L)	Garnet Leachability (mg/L)	Regulatory Limit (mg/L)
Ag	BDL to 0.151	<0.05	5.0
As	BDL to 0.048	<0.1	5.0
Ba	BDL to 0.482	<0.1	100.0
Cd	BDL to 0.007	<0.02	1.0
Cr	BDL	<0.05	5.0
Hg	BDL to 0.041	<0.001	0.2
Pb	BDL to 0.605	<0.5	5.0
Se	BDL to 0.048	<0.1	1.0

(a) BDL = below detection limit.
Source: Reed Minerals, 1995.

2.1.3.3 Chemical Characteristics of Media Used on Bridges. The Commonwealth of Pennsylvania funded a study of beneficial reuse options for spent ABM used to remove lead-based paint from bridges (Weyand and Sutton, 1990). As part of the project, samples of spent coal slag and spent copper slag ABM were analyzed to determine the total composition and TCLP leachability. The total composition is shown in Tables 2-6 and 2-7 for coal and copper slag, respectively. The TCLP results are shown in Tables 2-8 and 2-9 for coal and copper slag, respectively.

Two of the copper slag samples had low TCLP leachable lead (see samples 7 and 9 in Table 2-9). The authors note that all three copper slag samples contain a higher concentration of elemental iron and ferrous iron than the coal slag samples. Elemental iron reduces lead leachability, leading the authors to propose iron stabilization as a possible mechanism. They also note that samples 7 and 9 required significantly more acid addition to maintain a final pH of 4.8. The greater acid requirement indicates more reserve alkalinity which may have reduced lead leachability in the TCLP test.

Table 2-6. Total Chemical Composition for Spent Coal Slag Media

Element	Total Composition of Slag Sample (wt %)					
	1	2	3	5	6	8
Pb	0.15	0.26	0.47	0.20	0.28	0.50
Cu	0.00	0.00	0.00	0.04	0.07	0.01
Zn	0.02	0.03	0.04	0.27	0.42	0.16
Ti	0.59	0.59	0.60	0.62	0.60	0.71
Al	10.8	10.7	10.8	11.4	11.6	11.2
Si	22.5	21.7	22.2	21.6	21.8	20.2
Ca	2.86	2.79	2.93	2.86	2.79	1.22
Fe	16.6	18.4	16.5	15.5	15.0	20.1
Ni(a)	0.12	0.06	0.10	0.09	0.12	0.07
Ba(a)	0.09	0.09	0.09	0.22	0.22	0.22
Sr(a)	0.07	0.07	0.09	0.13	0.15	0.06
Cr(a)	0.10	0.07	0.12	0.06	0.07	0.08

(a) Estimated by x-ray fluorescence methods.

Table 2-7. Total Chemical Composition for Spent Copper Slag Media

Element	Total Composition of Slag Sample (wt %)		
	4	7	9
Pb	0.84	0.52	0.92
Cu	0.94	0.69	0.56
Zn	3.75	3.25	3.15
Ti	0.36	0.37	0.40
Al	6.0	7.4	7.1
Si	14.1	15.5	16.1
Ca	6.58	5.36	4.43
Fe	23.6	23.1	23.4
Ni(a)	0.20	0.15	0.15
Ba(a)	0.19	0.13	0.17
Sr(a)	0.03	0.05	No data
Cr(a)	0.29	0.21	0.21

(a) Estimated by x-ray fluorescence methods.

Table 2-8. TCLP Results for Spent Coal Slag Media

Element	TCLP Result for Slag Sample (mg/L)					
	1	2	3	5	6	8
Pb	6.9	22.0	25.0	25.0	13.0	23.0
Ag	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
As	<0.003	<0.003	0.005	<0.003	<0.003	<0.003
Ba	0.50	0.60	0.30	0.40	0.40	0.60
Cd	0.022	<0.005	0.036	0.011	0.014	<0.005
Cr	0.41	0.25	0.33	0.02	0.02	0.10
Hg	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002
Se	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004

Table 2-9. TCLP Results for Spent Copper Slag Media

Element	TCLP Result for Slag Sample (mg/L)		
	4	7	9
Pb	25.0	0.73	1.5
Ag	<0.01	<0.01	<0.01
As	<0.003	<0.003	<0.003
Ba	1.4	1.70	2.10
Cd	0.026	0.016	<0.005
Cr	0.10	<0.01	0.01
Hg	<0.0002	<0.0002	<0.0002
Se	<0.004	<0.004	<0.004

2.2 Characteristics of Other Similar Wastes

As part of the project, other wastes generated at Navy facilities with characteristics similar to ABM will be identified. Data on characteristics of the wastes and where/how they are generated by the Navy will be provided.

Wastes similar to ABM will be defined as a hard, granular matrix with a high silica and/or alumina content contaminated mainly with inorganics. Examples of such materials include:

- metals-contaminated soils
- casting sands
- catalysts
- ashes and condensed fumes
- slags
- construction and demolition debris
- refractory bricks
- metallurgical furnace dust.

2.2.1 Metals-Contaminated Soils

A variety of activities can contaminate soils with metals. The backstop at a firing range collects lead (possibly containing arsenic as a hardening alloy) and copper. Metal waste discharges from activities such as plating and paint removal. Fugitive emissions or leachate from waste piles, landfills, or sludge deposits also can add undesirable metal constituents to soil.

Soils consist of weathered mineral grains and organic materials in varying proportions. Soils typically are heterogeneous and may be stratified due to historical variations during the soil formation process. Soil layers form as a result of interaction between the soil and groundwater, atmosphere, and vegetation. The properties of the upper layers are particularly affected by biological activity of plants and microorganisms. As a result, the surface soil properties are strongly influenced by soil chemistry, moisture content, and climatic conditions.

The wide variations in natural soil properties and contaminant levels encountered in site remediation cannot be overemphasized. Not only do soil and contaminant conditions vary from site to site, but wide ranges of conditions frequently occur within one site. The process or equipment selected to handle contaminated soils must be able to accept wide variations in soil conditions and contaminant levels.

Many systems are available for classifying soil type and constituents. Most of these classifications include particle size as the primary physical parameter. Typical classifications, in order of decreasing size, are:

- gravel
- sand
- silt
- clay

The organic content of soil can vary from less than 1% in dry, sandy soils to more than 20% in soils that are exposed to water much of the time. The chemistry of the organic portion of soils is complex. The soil organic content will consist of high-molecular-weight humic materials and lower-molecular-weight organic acids and bases. The high-molecular-weight humic materials have low water solubility and high affinity for metals. The humic and fulvic acid fraction account for most of the metal immobilization due to soil organic matter. These acids immobilize metals by complexation and chelation mainly due to acidic sites. The lower-molecular-weight organics tend to mobilize metals. These nonhumic materials form water-soluble complexes with metals resulting in more mobile species (Czupyrna et al., 1989).

Other characteristics that help identify soil type and behavior include structure, color, density, type, and amount of organic and inorganic colloidal materials. Typical engineering properties, such as density and Atterberg limits, will indicate the handling properties of the soil. The solubility of metals in soil is controlled by factors such as pH, Eh, the ion exchange capacity, and the complexing and chelating effects of organic matter. Measurement methods and the significance of each of these factors have been described in several documents (Bodek et al., 1988; Cameron, 1992; Sims et al., 1984).

2.2.2 Casting Sands

Foundries use sand to make molds and cores to contain and shape metal during casting. The sand grains are held together with additives called binders. Mold-making techniques may use sand mixed with a small amount of clay and water or more complex binder systems such as silicates or organic resins such as phenolic-urethane polymers.

2.2.3 Catalysts

Catalysts used for industrial processes typically are in the form of a ceramic support carrying a small quantity of metal catalyst such as a chromium, nickel, or platinum group metal. The supporting ceramic often is a sphere of controlled particle size consisting mainly of alumina (Al_2O_3) and silica (SiO_2). In use, the catalyst becomes fouled with reactants or reaction products (Pavel and Elvin, 1994). Catalyst activity often can be recouped by thermal regeneration, but some of the particles break during the regeneration process. Once the catalyst particles become too small to be useful, they can become a waste disposal problem.

2.2.4 Ashes and Condensed Fumes

Fly ash is fine particulate waste collected from off-gas leaving processes such as smelting or coal combustion. Fly ash particles form in a high-temperature gas stream. At the typical combustion or processing temperature of about 2,900°F (1,600°C), the ash material is a molten sphere. As the particles cool, they retain a generally spherical shape. The particulate is collected by baghouses, electrostatic precipitators, or similar off-gas cleaning equipment. The particulate is mainly glassy, spherical silicates and aluminates material with particle sizes in the range of 4E-5 to 6E-3 in (1 to 150 micrometers [ìm]) (Gera et al., 1991). The fine particulate may be removed from the off-gas cleaning equipment as either a dry powder or a water slurry and then be sent to a storage pile for subsequent disposal or recycling.

Fumes are very fine particulates produced during high-temperature metal processing. Volatile metals or metal oxides evaporate and recondense to form the fume. One common example is condensed silica fume, a fine particulate consisting of over 90% silica. Condensed silica fume is a byproduct of ferroalloy production. Metal impurities may impart a hazardous waste characteristic. The fume is an artificial pozzolan with a very high activity due to its small particle size and amorphous structure. Volatile metals such as cadmium and zinc also are prone to fume formation. The fine-particle fumes are difficult to transfer by conventional materials-handling techniques (Popovic et al., 1991).

2.2.5 Slags

Slag is a fused solid consisting mainly of inorganic oxides of silicon, iron, and calcium with metallic impurities. Slag is a typical waste product from pyrometallurgical metal processing. The slag composition depends on the feed material source and the process used. Slags generally contain silica (SiO_2) as the main constituent along with fluxing salts (e.g., calcium and magnesium) and metal impurities from the ore.

Density, porosity, and leach resistance are the main properties considered in evaluating slag as a contaminated matrix. These properties vary depending on the method of producing the slag. The form of slag produced depends on the conditions used for cooling. Testing has indicated that faster slag cooling is important for reducing the mobility of metals. The general categories of slag are air-cooled, expanded, and granulated.

2.2.6 Construction and Demolition (C&D) Debris

C&D debris is bulky waste resulting from land clearing, building new structures, and remodeling or tearing down old structures (von Stein, 1993). The approximate overall average content of debris from demolishing structures in the United States is 53.8% concrete, 21.2% brick, 22.0% wood, 2.7% iron and steel, and 0.22% glass. Small amounts of a wide range of substances, including copper, lead, aluminum, plastic, paper, gypsum board, and asbestos, make up the rest of the debris. Crushed C&D debris usually has a soil or rocklike appearance and consistency. Concrete in C&D debris may contain steel or iron reinforcing bars which can complicate processing the waste for reuse. Although C&D debris usually is not hazardous waste, the potential for hazardous or toxic contaminants should not be ignored. Possible sources of contaminants in C&D debris include:

- asbestos used for insulation or structural applications
- creosote, pentachlorophenol, or chromated copper arsenate preservatives in wood
- polychlorinated biphenyls (PCBs) in electrical components
- metals (particularly lead) in paint pigments.

2.2.7 Refractory Bricks

Refractory bricks are high-performance ceramic materials used to line high-temperature processing equipment. Refractory bricks are made from chromite or similar chromium oxide materials. The bricks deteriorate in use and are replaced periodically during furnace maintenance (Martin et al., 1987). Many refractory bricks contain percentage levels of chromium and can exhibit the D007 chromium toxicity hazard characteristic. The bricks also may become contaminated by process materials during use.

2.2.8 Metallurgical Furnace Dust

In production of steel in electric arc furnaces (EAFs), feed materials are charged into a refractory-lined furnace and melted by an electric current arcing between electrodes through the metal feed. EAFs accept a high proportion of scrap in the feed. The scrap steel is often galvanized, coated, or plated to improve its function. The most common surface treatments are zinc galvanizing, lead terne coating, and cadmium plating. Each of these plating metals tends partition to the vapor phase as a fume. The fume condenses and is then removed by a dry filtration or wet scrubbing operation. The EAF process removes many metal impurities from the scrap by volatilization. Because of the ability to remove impurities, the EAF processes almost 100% scrap (with a maximum of 30% galvanized scrap feed). The high level of scrap feed to the EAF causes elevated levels of zinc, cadmium, or lead in the fumes from the furnace. Due to the presence of these metals, emission control dust/sludges from EAFs are a RCRA-listed waste (K061).

The composition of the dust formed varies directly with the type of steel being produced and the constituents being volatilized from the furnace. Specifications for carbon steels are generally less restrictive than specifications for high-alloy steels. Carbon steel making can start with an initial charge of scrap containing higher loadings of plating and other impurities. Due to the higher scrap loading, the dust generated from the production carbon steels may contain more lead and other impurities than the dust from the production of specialty, stainless, and alloy steels. Dust from making higher alloy steels will contain more chromium and nickel. Typical concentration ranges for EAF dust from specialty-steel and low-ally producers are shown in Table 2-10.

Table 2-10. Typical Composition Ranges for EAF Emission Control Dust

Element	Metal Content Range for Specialty-Steel Producers (weight %)	Metal Content Range for Low-Alloy Producers (weight %)
Cadmium	0.04 to 0.08	0.01 to 0.07
Lead	0.54 to 1.36	0.21 to 45.28
Zinc	2.27 to 8.52	0.79 to 3.49
Nickel	1.83 to 3.60	0.13 to 0.24
Iron	22.96 to 25.81	4.07 to 43.09
Chromium	7.64 to 11.71	0.01 to 3.43

Source: Hanewald et al., 1992.

3.0 RECYCLING AND REUSE OPTIONS

This section describes the operating features and applications of recycling and reuse options for ABM and similar wastes. The recycling methods are arranged generally in the order of decreasing value of the product produced. Methods to recycle spent ABM are organized into the following groups:

- reconditioning and reuse of spent ABM
- processing to convert spent ABM into high- or medium-value ceramic products
- using spent ABM as a raw material in portland cement
- using spent ABM as aggregate in portland cement concrete
- using spent ABM as aggregate in asphaltic concrete
- using spent ABM as a basic construction material
- processing to convert spent ABM into low-value ceramic products
- using spent ABM as a flux-forming addition in a smelter.

3.1 Reconditioning and Reuse of Spent Abrasive

This section describes methods to process and reuse spent ABM. The spent ABM can be cleaned using physical separation to remove fines and/or hard metal or metal oxide particles and then reused.

3.1.1 Description of Recycling Option

Reclamation of ABM implies collecting the ABM after use and processing to remove undesirable components in the ABM. Reclamation of spent ABM applies simple unit operations, but there are challenges to successful implementation. Collecting and storing the spent media requires equipment and procedures not used in normal blast cleaning done outdoors on large structures such as ships. Once the spent ABM is collected, several processing steps are needed to return the material to its original quality to allow reuse.

Collection and handling of spent ABM can be conducted with minimal concern about adding extraneous contaminants when the spent ABM is to be discarded. Spent ABM collected for disposal usually contains a high proportion of soil and may contain general site trash including paper, cloth, or plastic scraps and small metal parts (e.g., bolts, screws, and brackets). Additional care must be taken to collect the spent ABM for reclamation.

A wide variety of undesirable components including debris from the work area, ABM fragments, and paint particles and contaminants removed from the hull are intermixed with the spent ABM. When the ABM impacts the surface being cleaned, some of the media fracture, producing fine particulates that must be removed during the reclamation process. A high proportion of fines will:

- reduce the effectiveness of coating removal
- increase dust generation when the grit is reused.

Small bits of steel and metal oxide are cut away from the ship hull during the blast cleaning process. If these hard particles are not removed by the reclamation process, they will strike the surface being cleaned creating high residual stress in small areas. These stressed spots can be points of initiation of fatigue fractures or increased corrosion.

Simple screening is unlikely to clean the spent ABM sufficiently to allow reuse. Because the contaminants in the ABM have a wide range of physical and chemical properties, successful reclamation processing requires more sophisticated methods. Screening to remove oversize debris is always the first step. This first simple cleanup is followed by various combinations of magnetic separation, water-assisted beneficiation, and thermal treatment to produce an acceptable reclaimed ABM product.

3.1.2 Advantages of Recycling Option

Reclaiming spent ABM for reuse provides reduction in resource consumption with minimum transportation and handling. Onsite recycling is the next level in the U.S. EPA's waste reduction hierarchy, when waste production cannot be prevented at the source.

3.1.3 Limitations of Recycling Option

Reclamation requires the use of a tough, fracture-resistant ABM which increases the unit cost, and purchasers often prefer to minimize even the initial cost. Sand, the cheapest media, is unsuitable for reclamation. Slag-based media cost more per ton but will survive a few cycles of reuse, and garnet media, which cost even more, can be reused for many cycles. The number of reuse cycles attained in practice will depend on many factors including the air pressure used to apply the ABM, the type of coating removed, and the worker's experience level.

A significant fraction of undesirable materials (e.g., ABM fragments, paint chips, and hard particles) must be removed from the spent ABM. These undesirable components will need to be managed as waste and may be listed as hazardous waste under RCRA.

The possible presence of hard particles in the reclaimed ABM increases the concern for creating high stress points in the ship hull when the ABM is reused.

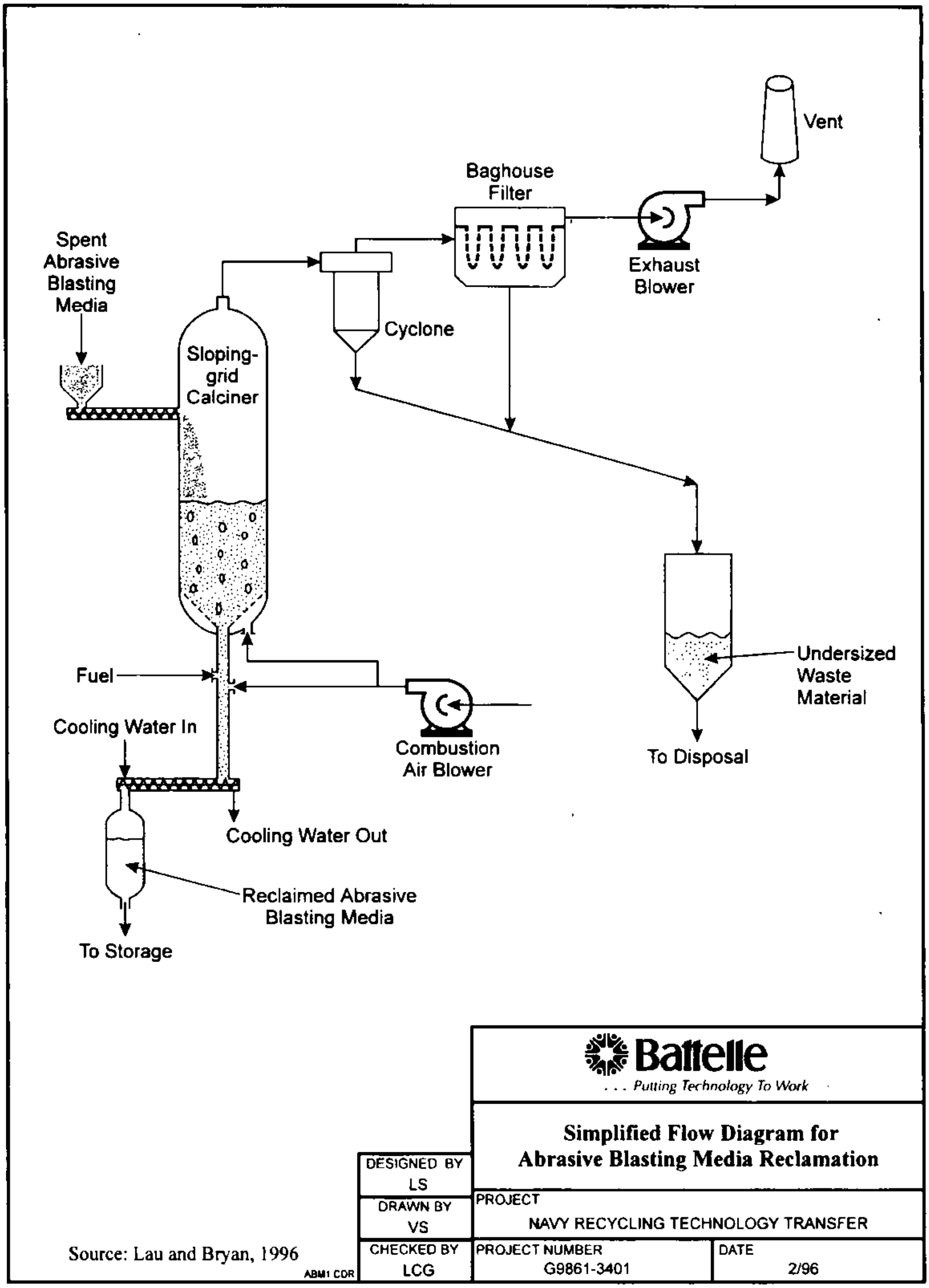
The possible presence of impurities in the reclaimed ABM increases the concern for high airborne contaminant levels in the work areas and for contaminating the ship hull when the ABM is reused.

3.1.4 Example Applications

3.1.4.1 Thermal Processing of Spent ABM. The U.S. Navy and the Institute of Gas Technology (IGT) have been developing and testing thermal processing to reclaim spent ABM. The technology is an extension of a fluidized-bed coal combustion system developed by IGT that has been applied to the reclamation of foundry sand. The fluidized-bed ABM treatment system is illustrated in Figure 3-1.

The spent ABM is conveyed from a storage pile to pass through a grizzly and a 0.5-in (12-mm) vibrating screen to remove oversized debris and then through a magnetic separator to remove ferromagnetic particles. After the initial cleaning, the spent ABM is fed by a screw conveyor into the top of the fluidized-bed calciner. A mixture of gas and air is introduced into a pipe in the bottom center of the bed. The air and natural gas burn directly in the bed to heat the spent ABM to 1,200°F to 1,600°F (650°C to 870°C) and to oxidize the organic portion of paint chips to CO_2, H_2O, and metal oxides.

The gas flow in the calciner provides mixing and size classification in addition to the heating action. The ABM bed is well agitated and heated by the burning gas to ensure good combustion of the paint chips and removal of the fine particulates. Metal oxides from the burned paint chips and undersized particles of broken ABM are entrained in the gas stream and lifted out of the calciner. The clean ABM flows down along the sloped grid and exits the bottom of the calciner past the incoming air and gas.



Source: Lau and Bryan, 1996

Figure 3-1. Simplified Flow Diagram of Abrasive Blasting Media Reclamation

The clean ABM is moved from the bottom of the calciner through a water-cooled screw conveyor and placed into storage for reuse. The process can reclaim between 80% to 90% of the spent ABM.

The metal oxides and fine particles are removed from the off-gas for disposal. Off-gas from the calciner is cooled with a water spray and then passed through a cyclone separator and bag filter to collect particulates for disposal.

3.1.4.2 Physical Reclamation of Spent ABM. Pittsburgh Mineral and Environmental Technology owns and operates mobile units for recovery of spent abrasive contaminated with paint chips containing hazardous metal contaminants. The most common application is treatment of abrasive used to remove lead-based paints from bridges, overpasses, and other steel highway structures. The spent abrasive is a complex mixture of abrasives, paint chips, steel, and rust. The process is reported to separate the spent abrasive stream into three reusable fractions:

- paint chips
- coarse abrasive
- undersized abrasive.

The lead-bearing paint chips can be sent to a lead smelter for reprocessing, the coarse abrasive is reused, and the undersized fines are used as feed for other ceramic products such as bricks.

The abrasive processing unit is mobile and can be set up at the paint removal site to process material at the rate of about 2 to 5 tons (1.8 to 4.5 metric tons) per hour. Spent abrasive is screened to remove coarse materials such as debris and larger paint chips. Magnetic separation then removes the steel particulates and other ferromagnetic materials. The nonmagnetic portion is fed onto a gravity separation table to separate the fine particulate from the coarse abrasive based on the apparent density of the particles (as determined by their respective gravity, shape, texture, and size). The coarse fraction can be reused as abrasive. The fine fraction is further treated by electrostatic separation based on differences in surface conductivity to separate the paint chips from the fine abrasive particles. The paint chips can be fed to a metal smelter, and the fine abrasives can be fed to a brick-making process. The process is reported to be accepted by the U.S. EPA Region III and the Pennsylvania Department of Environmental Resources as a recycling process for abrasive contaminated with lead-bearing paint chips (Gilbert and Weyand, 1990).

3.1.4.3 Soil Washing to Clean Spent ABM. Westinghouse Electric Corporation has developed a cleaning system for spent sandblasting abrasive used to remove lead-containing paint. The technology is based on Westinghouse research in soil washing. The system is reported to operate at a throughput of 20 tons (18 metric tons) per hour. Abrasive is cleaned with water-based leachates, which are continuously recycled in the soil washing system. The end products are cleaned abrasive, which is reported to be suitable for reuse, and the leach solution, which can be treated by chemical precipitation or membrane separation.

3.2 Use Spent Abrasive as a Raw Material in Ceramic Manufacture

This section describes ways to use spent ABM and similar wastes as a raw material in making medium- or high-value ceramic products. Ceramic products made from ABM or similar wastes will be competing with products in the Standard Industrial Classification (SIC) group 32 (OMB, 1987). Economic characteristics indicating the size of the market for products in SIC group 32 are summarized in Table 3-1.

Table 3-1. Summary of Ceramic Product Market Characteristics

Industry/SIC	1987		1992
	Number of Establishments in SIC	Total Value of Shipments ($ million)	Total Value of Shipments and Inventory ($ million)
Stone, clay, and glass products/32	16,166	61,477	62,479
Flat glass/321	81	2,549	2,082
Glassware /322	522	8,339	9,055
Processed glass products/323	1,432	5,429	6,955
Cement/324	215	4,335	4,035
Structural clay products/325	598	2,915	2,864
Pottery/326	1,006	2,416	2,752
Concrete, gypsum, and plaster products/327	9,814	24,427	23,053
Cut stone and stone products/328	745	841	1,007
Misc. nonmetal mineral products/329	1,753	10,226	10,677

Source: U.S. Department of Commerce (1995, Table 1246).

The SIC group 32 has not been a strong growth or profit area for several years. The total value of shipments increased only 1.6% between 1987 and 1992. Most or all of this increase can be accounted for by inflation. Profit for each dollar of sales in 1990 was 1.8 cents. The industry showed a loss of 0.7 cent per dollar of sales in 1992 but rebounded to show a profit of 3.4 cents per dollar of sales in 1993. For comparison, the average profit for all manufacturing concerns was 5.4 cents per dollar of sales in 1993 (U.S. Department of Commerce, 1995, Table 890).

3.2.1 Description of Recycling Option

Spent ABM and similar wastestreams consisting predominantly of silica and/or alumina with low levels of metal contaminants can be processed thermally to form glass or ceramic products or be used as raw materials in ceramic manufacture. The glass or ceramic matrix can effectively immobilize many metal impurities. The metal contaminants may even impart desirable properties such as coloration or increased hardness to the product.

Formation of ceramic products may be accomplished by either sintering or melting. In both processes, prepared waste material is heated to form the ceramic. Most thermal treatment processes require feed material to be within a narrow particle size range. Size reduction and/or pelletization are usually needed to obtain the required size.

In sintering, the waste is prepared by mixing with clay or other silicates and possibly water and additives. The mixture is pressed or extruded to form bricks, pellets, or other shapes. The formed products are treated at high temperature but below the bulk melting temperature where particles join or sinter to form a solid ceramic piece.

Vitrification processes also require feed preparation. The chemical additions and mixing may be used to promote oxidation-reduction reactions to improve the properties and stability of the final product. Silica sources such as sand or clay may also be needed. Vitrification processes operate by heating the pretreated waste to melting temperatures. The molten treated waste flow exits from the melter into a waste-forming or quenching step. The melt can be formed in a metal- or sand-coated mold to form a monolithic product or quenched in a water bath to produce a frit. Vitrification to form low-value aggregates, as described in Section 3.7, uses the same basic approach but typically starts with wastes that contain complex mixtures of contaminants.

Gases released from the thermal treatment unit are processed through an emission control system. Particulates may form due to carryover, metal fuming, or anion fuming. The particulates are removed by knockout boxes, scrubbers, and/or venturi separators. Particulates are separated from the scrubbing fluid by filtration and are returned to the treatment system. Acid gases, such as sulfur dioxide from sulfates, are removed by scrubbing with sodium hydroxide.

A wide range of high- to medium-value products could be made from ABM or similar silicate or aluminate wastes. Possible products include:

- ceramic tile
- finished and rough dimension stone
- brick and structural clay items
- frit.

Ceramic tiles are thin ceramic squares or rectangles, usually with a decorative finish on one surface used for appearance in architectural applications.

Dimension stones are block, panel, or curvilinear shapes used for appearance and/or structural functions. The stone shape can range in size from the base of a pen and pencil set to large building stone.

Brick and tile shapes are made from fired clay and used for load bearing or other applications (e.g., non-load-bearing fire walls, sound absorption walls, or drainage tiles). These ceramic items generally are simple rectangular or cylindrical shapes with moderate surface finish and size tolerance requirements.

Frit is a raw material for ceramic manufacturing. A waste can be vitrified to destroy organic impurities and improve its physical properties and then further processed in an existing manufacturing plant to form products such as refractory fibers or abrasives.

3.2.2 Advantages of Recycling Option

Thermal treatment to produce useful products from wastes has the potential to reduce negative effects on human health and the environment over the product's life-cycle and to reduce the costs for management of wastes (Carter and Tsangaris, 1995). The main purpose for using the vitrification process is to convert a material that would have been a waste into a value-added product. Using waste material to replace raw materials in product manufacture decreases demand on resources and reduces the volume of waste discharged. In addition to value created by the product, costs for treatment and disposal are avoided. The end user of the resulting ceramic product may be closer or more distant, so transportation may have a positive or negative effect on the economics of waste vitrification depending on the location of the vitrification plant and the user.

The high-temperature vitrification or sintering process causes significant changes in the physical or chemical form of the matrix and the contaminants. Organic constituents such as resin in paint chips are oxidized to their mineral components. Metal contaminants are incorporated into a durable, leach-resistant mineral matrix.

3.2.3 Limitations of Recycling Option

Contaminants in the waste product will change the hardness, toughness, color, or texture of ceramic products which may reduce product performance or acceptance. Only selected wastestreams can be converted into high-value ceramic products. To provide a high-value product such as decorative finished dimension stone or frit for making high-performance refractories, the initial wastestream must contain a limited number of contaminants. For example, hydroxide sludge from treatment of plating or etching baths containing a single metal contaminant is converted by vitrification on a commercial scale to high-value products (Hazardous Waste Consultant, 1990). Purely cosmetic features usually are not strong determinants of product acceptance for the structural products but may still reduce acceptance in some applications. For example, the dark or earth tones that occur in vitrified products containing a wide range of metals are undesirable in applications where the item needs to be visible, such as railings, parking lot stops, or road barriers.

The process is capital- and energy-intensive, but the product value and avoided disposal costs will contribute to the economic viability of the option.

Volatile metals such as arsenic, mercury, or beryllium are difficult to treat and can be present only at low concentrations. Wastes containing arsenic will require some combination of pretreatment, special processing conditions, and/or off-gas treatment systems to minimize arsenic volatilization. If reducing conditions can occur in the melt, cadmium, lead, and zinc can vaporize and enter the off-gas stream (Hollander et al., 1995).

The product potentially would be used in close proximity to the general public and thus would be required to meet high standards of contaminant immobilization and performance.

3.2.4 Example Applications

3.2.4.1 Using Abrasive Blasting Media to Make Bricks. Spent ABM is an ideal candidate for beneficial reuse in the manufacture of structural fired clay products, e.g., bricks. The U.S. Navy, David Taylor Research Center in Annapolis, Maryland, has been studying this alternative for the past several years. The bricks are produced using spent ABM to meet the specifications for strength and absorption, while metals are incorporated into a chemically stable, complex silicate phase during brick firing. Data collected thus far indicate that metal leachability in the final clay product increases with decreasing particle size of the spent ABM (Thomas, 1992).

Pittsburgh Mineral and Environmental Technology performed a study of beneficial reuse of ABM from bridges for the Pennsylvania Department of Transportation. The study concluded that using spent ABM to replace sand in brick making was the most promising option. Test bricks were made with 10%, 20%, and 40% of the normal brick mix. Unprocessed ABM gave poor results. However, when the ABM was crushed and screened to reduce particle size to below 20 mesh, the test bricks were acceptable (Weyand and Sutton, 1990).

3.2.4.2 Using Foundry Slag to Make Bricks. Granulated slag from cast iron production was ground to give a Blaine specific surface area of 100 ft^2/oz (3,200 cm^2/g). The ground slag was used in combination with lime and sand to produce 1.6-in (4-cm) cubes for testing. The reported compressive strength ranged from 1,860 to 2,480 psi (12.8 to 17.1 MPa) (Malolepszy et al., 1991).

3.2.4.3 Using Incinerator Ash to Make Bricks. Research has been reported on the properties of brick made with incinerator-derived ash used in combination with cement and limestone screenings. The ash was produced by a refuse-derived-fuel facility. Two series of tests were carried out with bricks formed with 20% and 40% ash. In the two series, the cement content varied from 4% to 10% and the water content varied from 2% to 8%. The remainder of the brick composition was normal limestone sand. The reported compressive strength for the 10% cement, 40% ash, and 8% water case was 7,500 and 6,800 psi (52 MPa and 47 MPa) for air-dried and soaked curing conditions, respectively. The compressive strength increased with increased cement and ash content (Ali et al., 1992).

3.2.4.4 Using Spent Catalysts to Make Bricks. Cherokee Environmental Group of Sanford, North Carolina processes nonhazardous spent catalysts for use as aggregate in brick making. Catalysts are crushed and size-graded to form an alumina/silica sand which replaces sand in brick making.

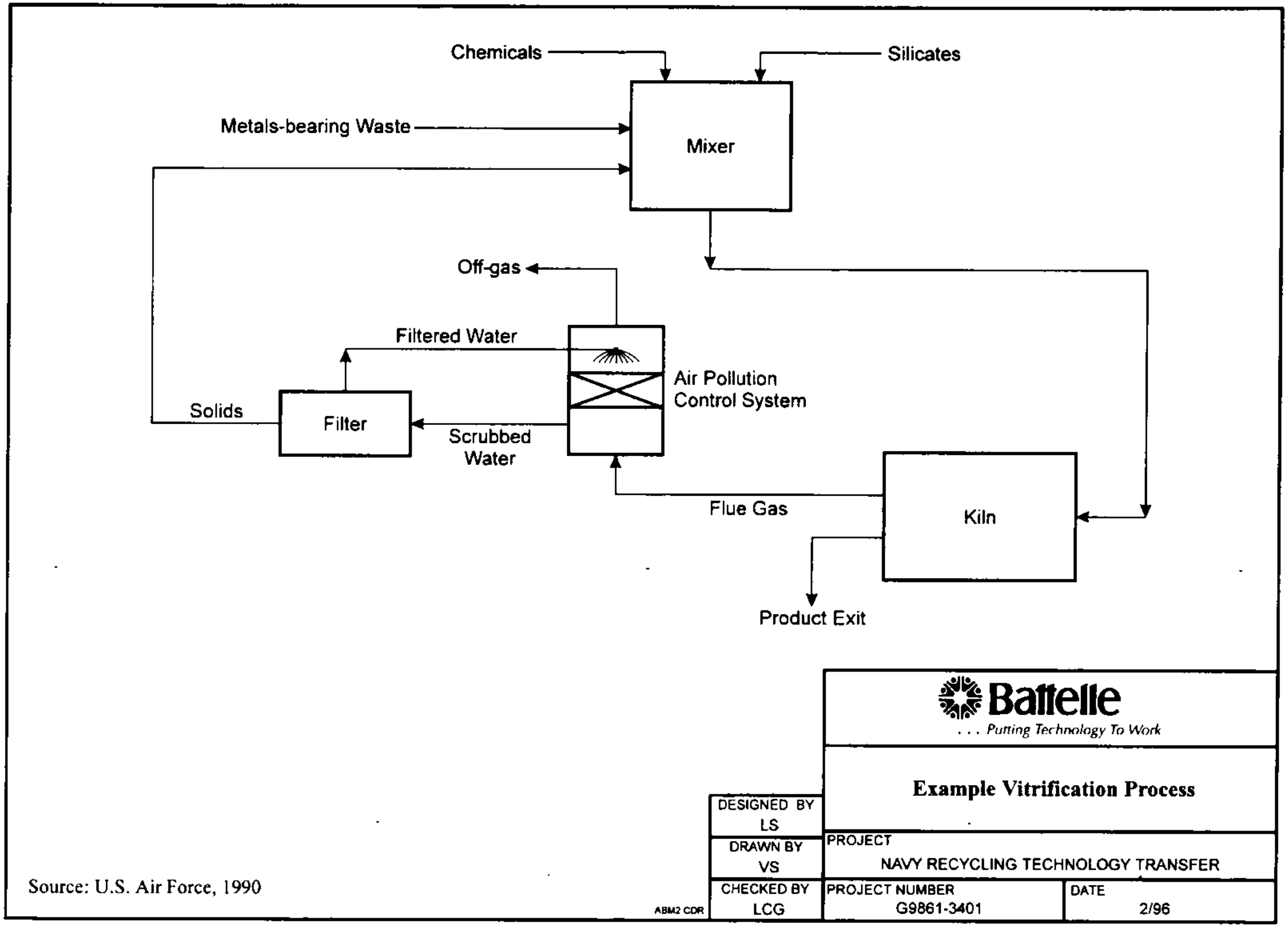
3.2.4.5 Metal-Containing Waste Sintering. The Ceramic Bonding, Inc. of Mountain View, CA provides a treatment method to convert waste into an alumina-silicate ceramic used to physically and chemically immobilize metal contaminants. The waste is mixed with a proprietary alumina silicate material and extruded into pellets. The pellets are fired at 2,000°F (1,090°C) to form a ceramic solid called Armorite™. This material reportedly is leach-resistant and is suitable for use as a ceramic making raw material or as a construction aggregate.

Waste materials amenable to treatment include filter cakes, foundry sand, ash, and sludge. The process treats inorganic wastes containing cadmium, chromium, cobalt, copper, lead, nickel, vanadium, or zinc. Metals that will volatilize under process conditions, such as mercury or arsenic, cannot be treated. Ceramic Bonding is reported to be planning to offer processing of F006 waste and some site remediation wastes as a RCRA-exempt recycler.

3.2.4.6 Metal-Containing Waste Vitrification. Pollution Control Systems of Dublin, Ohio markets a process to recycle metal-contaminated sludge wastes into feed material for architectural, abrasive, and refractory ceramic products. The company installs and operates a process system at the waste generator's site. The U.S. EPA is reported to have accepted the process as a recycling process exempt from RCRA permitting based on testing and performance data. Applicable waste types include D characteristic wastes and F and K listed wastes such as F006 and K061.

The process, as illustrated in Figure 3-2, involves three primary components:

- mixing
- vitrification
- off-gas treatment



Source: U.S. Air Force, 1990

Figure 3-2. Example Vitrification Process.

All incoming generator materials are processed on a batch basis. Prior to entering the reactor, each batch of waste is tested to determine requirements for raw materials addition. The waste is typically a sludge to which water and chemicals are added. The chemical additions and mixing promote a series of oxidation-reduction reactions to improve the properties and stability of the final product. Following the reaction phase, silica sources such as sand or clay are added. The mixed materials are transferred to a surge tank to provide continuous feeding to the vitrification operation.

Vitrification operates continuously with blended/reacted feed entering the vitrifier where it is heated to form a molten mass. The material travels through the vitrification unit to an exit overflow. The operating temperature and residence time of the vitrification unit are determined by laboratory analysis. The molten treated waste flow exits from the melter into a waste-forming or quenching step. The melt can be formed in a sand-coated mold or quenched in a water bath depending on the type of product needed. The resulting ceramic material is packaged for shipment to end users.

Gases released from the vitrification unit are processed through an emission control system. Particulates may form due to carryover, metal fuming, or anion fuming. The particulates are removed by knockout boxes, scrubbers, and/or venturi separators. Particulates are separated from the scrubbing fluid by filtration and are returned to the treatment system. Acid gases, such as sulfur dioxide from sulfates, are removed by scrubbing with sodium hydroxide to form sodium metasulfite. The sodium metasulfite reportedly is collected and sold.

3.2.4.7 Using Fly Ash to Make Clay Products. Fly ash from a coal combustion, steam-generating plant was used in combination with clay, cement, or lime to make extruded bricks. The resulting bricks were tested for shrinkage, weight loss, tensile strength, compressive strength, and mineralogy. Addition of fly ash was reported to improve the quality of the bricks due to the grain size, shape, and the pozzolanic activity of the fly ash (Temini et al., 1991).

3.3 Use Spent Abrasive as a Raw Material in Portland Cement Manufacture

This section describes use of spent ABM and similar waste as a raw material in making portland cement. Cement is made from a mixture of limestone, sand, and clay prepared and burned to form clinker which is then ground. The expected U.S. production of portland and masonry cement in 1995 is 87,300,000 tons (79,300,000 metric tons). Portland cement makes up about 96% of the total U.S. cement output (Solomon, 1995a). Many sandlike waste materials can provide useful calcium, silica, alumina, or iron inputs for cement makers. Due to the large volume of cement produced, significant quantities of spent ABM can be consumed as replacements for cement raw materials and at the same time conserve resources. The European cement industry reports that use of secondary raw materials, such as granulated blast furnace slag and coal combustion fly ash, has reduced mineral and energy resource consumption (Lawton, 1992).

3.3.1 Description of Recycling Option

Manufacture of hydraulic cement offers possibilities for recycling of contaminated waste materials. Making cement requires a significant input of energy and raw materials. Petroleum-contaminated soils are used as input to cement kilns by a variety of companies. Petroleum-contaminated soils supply both heating value and a silica source (U.S. EPA, 1992, EPA/600/R-92/096). Opportunities also exist for using nonhazardous metals-contaminated solids to make cement, particularly when the waste has a high alumina or iron oxide content.

Portland cement is made by heating mixtures containing lime, silica, alumina, and iron oxide to form clinker which is then ground. About 3% to 5% of calcium sulfate, usually as gypsum or anhydrite, is added during grinding of the clinker. The gypsum aids in the grinding process and helps control the curing rate of the cement product (Collins and Luckevich, 1992). The gypsum is intermixed during grinding of the clinker. The main constituents of portland cement are tricalcium silicate (C_3S), dicalcium silicate (C_2S), tricalcium aluminate (C_3A), and tetracalcium aluminoferrite (C_4AF).

Specifications for limestone feed for cement making require that the calcium carbonate ($CaCO_3$) content be greater than 75% and the magnesium carbonate ($MgCO_3$) content be less than 3%. Because the raw materials need to be finely ground, chert nodules and/or coarse quartz grains are undesirable (Tepordei, 1993b).

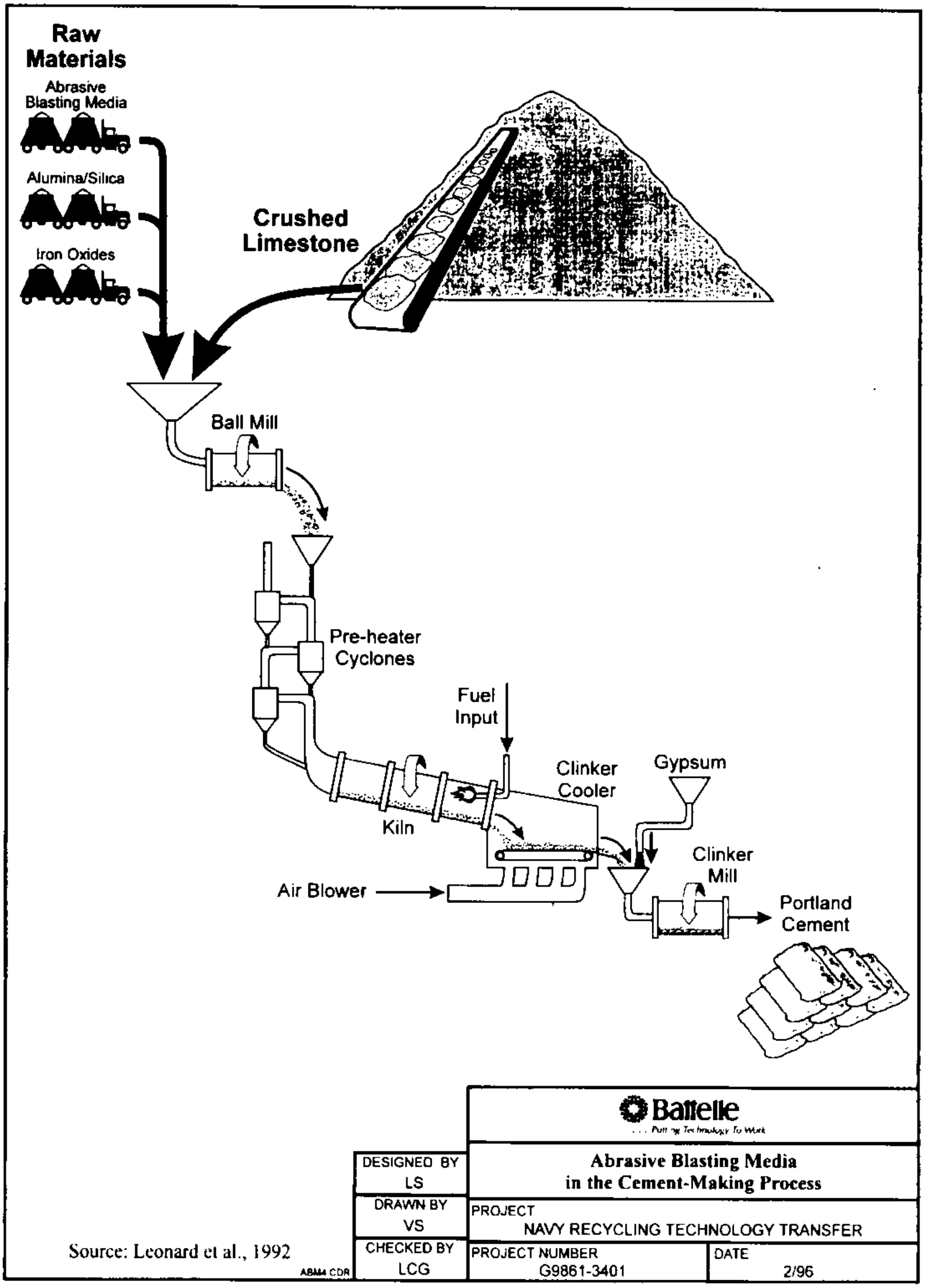
Raw material burning typically is done in a rotary kiln. The kiln rotates around an inclined axis (see Figure 3-3). The raw materials enter the raised end of the kiln and travel down the incline to the lower end. The kiln is heated by combustion of coal, gas, or oil injected at the low end of the kiln. As the raw materials move through the inclined, rotating kiln, they heat to a temperature greater than 2,600°F (1,430°C).

The residence time for solids is 1 to 4 hours, and the residence time for gases is about 10 seconds. The high temperature causes the following physical and chemical changes (U.S. EPA, 1982, EPA/600/2-82/013):

- evaporation of free water
- evolution of combined water
- evolution of carbon dioxide from carbonates
- partial fusion of the feed materials
- reactions among lime, silica, alumina, and iron to form the clinker.

During burning, lime combines with silica, alumina, and iron to form the desired cement compounds. The heating results in a product called clinker. Clinker consists of a granular solid with sizes ranging from fine sand to walnut size. The clinker is rapidly cooled, mixed with additives such as gypsum, and ground to a fine powder to produce the final cement product.

The American Society for Testing and Materials (ASTM) specifies five basic types of portland cement. Type I is intended for use when the special properties of the other types are not required. Type IA is for the same uses as Type I where air entrainment is desired. Air entrainment is a technique to improve the freeze/thaw resistance of the concrete and reduce the mix viscosity without increasing water. Type II is another general-use cement but offers decreased heat generation during curing and increased resistance to damage from sulfate salts in the soil. Type IIA is similar to Type II but is intended for use where air entrainment is desired. Type III is formulated to maximize early strength production. Type IIIA is the air entrainment version of Type III. Type IV is intended for use where the heat generation must be minimized. Type V is for use when sulfate resistance is desired. The main constituents of portland cement typically are tricalcium silicate (C_3S), dicalcium silicate (C_2S), tricalcium aluminate (C_3A), and tetracalcium aluminoferrite (C_4AF). Example compositions for the types of portland cement are shown in Table 3-2.



Source: Leonard et al., 1992

Figure 3-3. Abrasive Blasting Media in the Cement-Making Process.

Table 3-2. Examples of Compositions of Portland Cement Types

Cement Type	C_3S (wt %)	C_2S (wt %)	C_3A (wt %)	C_4AF (wt %)
I and IA	49.6	24.0	11.0	8.0
II and IIA	40.9	34.4	5.6	12.9
III and IIIA	59.3	14.1	9.3	7.9
IV	25.3	51.5	4.9	11.6
V	41.0	39.0	3.7	10.0

Source: Bogue, 1955.

3.3.2 Advantages of Recycling Option

Cement kilns have the capacity to recycle large quantities of waste. The kilns are widely distributed throughout the country, so long shipping distances can be avoided in many cases. For example, there are 11 cement manufacturers currently operating 20 portland cement kilns in the state of California. In 1989 alone, these operations reported the cumulative production of more than 10,400,000 tons (9,400,000 metric tons) of cement clinker. Due to gaseous losses during the calcining reaction, about 13,500,000 tons (12,250,000 metric tons) of mineral feedstock was required to generate the cement. Therefore, if only one tenth of 1 percent of the required feedstock for each of these kilns were dedicated to recycling of metal-bearing wastes, up to 13,500 tons (12,250 metric tons) of hazardous waste could be diverted from landfill disposal in just the state of California each year (Leonard et al., 1992).

Spent ABM and similar wastes also are good candidates for recycling as replacements for cement raw materials. Wastes high in alumina (such as bottom or fly ash, ceramics, and aluminum potliner) or iron (e.g., slag ABM, iron mill scale, foundry waste) are particularly good candidates. Silica and calcium also are beneficial ingredients, but these usually are provided in sufficient quantities by the quarry rock and therefore are not in as much demand.

Cement kilns provide high operating temperatures and long residence time, which cause significant changes in the physical and chemical form of the matrix and the contaminants. Organic contaminants are oxidized to their mineral components. Metal contaminants are incorporated into the portland cement matrix.

The high alkali reserve of the cement clinker reacts to form alkali chlorides (sodium, potassium, calcium), preventing evolution of acidic vapors in the off-gas. However, the chloride content of the wastes must be limited to avoid excessive kiln dust production. Most of the alkali chlorides vaporize and increase the quantity of kiln dust. Kiln dust containing a high proportion of alkali chlorides cannot be recycled to the cement kiln because soluble chlorides alter the setting rate of the cement product.

3.3.3 Limitations of Recycling Option

Recycling into portland cement is applicable to only certain types of wastes, based on chemical composition, contaminant levels, and other criteria (Bouse and Kamas, 1988a; 1988b):

- Aluminum, iron, and sometimes silica are the primary constituents which the kiln operator needs to purchase to supplement the naturally occurring concentrations in the quarry rock. Ores typically comprise 40 to 50% by weight of these constituents.

Therefore, waste materials should contain at least 20% or more of these constituents to be attractive substitutes for the ore materials.

- Combustion to heat the raw materials and decomposition reactions during formation of cement clinker generate large volumes of off-gas, which must be controlled and cleaned.

- Elevated concentrations of Na, K, S, Cl, Mg, and Ba can degrade the quality of cement or increase the volume of kiln dust waste produced. The plant chemist will be the final authority on whether a given waste material is compatible with the mix design.

- Recycling operations should be designed to avoid significant risk due to metals concentrations in the clinker or off-gas. Total metals concentrations in the recycled wastes should in general be <1%, and the clinker should be tested to ensure that the metals present are not highly leachable. Waste with highly toxic and volatile metals such as As or Hg should not be recycled in this manner.

Cognizant regulators should be contacted prior to proceeding with the recycling project. RCRA regulations discourage the land application of recycled hazardous materials (U.S. EPA, 1990c, Definition of Solid Waste). In most cases, special wastes or state-regulated wastes may be recyclable, subject to state or local restrictions or policies. Nonhazardous silicate and aluminate wastes are used as raw material substitutes in portland cement manufacture on a commercial scale. Using wastes containing RCRA metals may be possible, but commercial application is limited by the requirements of the Boiler and Industrial Furnace regulations.

3.3.4 Example Applications

3.3.4.1 Using Spent Abrasive Blasting Media to Make Cement. The Naval Facilities Engineering Service Center (NFESC) in Port Hueneme, California, along with Southwestern Portland Cement Co., Mare Island Naval Shipyard, Radian Corporation, and Battelle, have been studying the recycling of spent ABM as a raw material for the manufacture of portland Type I cement for construction purposes. The ABM is a silicate slag containing moderate levels of iron (Fe) and replaces some of the iron ore that normally is used in cement manufacture. The silica and alumina in the ABM are also useful ingredients in the cement product.

The spent copper slag ABM was hazardous in the state of California because of its Cu content, but is not classified as a RCRA hazardous waste. Consequently, this recycling demonstration was conducted under a Research & Development (R&D) variance issued by the California EPA.

During the demonstration tests, ABM was introduced as about 1% of the total feedstock of the kiln, and emissions monitoring was conducted to identify any fluctuations in the air emissions concentrations from the process. The final product was then subjected to physical and chemical analysis to determine the structural integrity of the product and whether the metals are bound in the crystalline structure of the cement. The results of these tests showed that the ABM in these proportions did not significantly increase the metals content of the clinker or lead to undesirable air emissions (Leonard et al., 1992).

The spent ABM at Mare Island Naval Shipyard is hazardous in the state of California and, if no recycling and/or reuse option were available, would have to be treated by stabilization/solidification and disposed of in a hazardous waste landfill. This technology makes beneficial reuse of the ABM by incorporating it into portland cement, where resulting metal concentrations are low and the metals are physically and chemically immobilized in the asphaltic concrete matrix.

Using ABM as a raw material in portland cement presents a cost savings for the waste generator and makes money for the operator of the cement kiln. In this Mare Island Naval Shipyard demonstration, the total fee charged by the kiln operator has been about $195/ton for about 4,000 tons (3,600 metric tons) of recycled spent ABM. The kiln operator requires the fee to cover costs for the following activities associated with using the metal-contaminated ABM as raw material:

- transporting the spent ABM from the generator's site in northern California to the cement plant in southern California
- determining feedstock proportions and process modifications to accommodate the waste materials
- sampling and analyzing the clinker
- sampling and analyzing air emissions from the stack
- engaging in regulatory interaction to obtain necessary permits or variances.

The only significant cost element not included in the $195/ton figure is the cost of ABM screening and debris disposal, which was borne by the shipyard and probably amounted to less than $10/ton.

The unit cost for managing the Mare Island Naval Shipyard spent ABM as California hazardous waste was about $660/ton. The waste management unit cost includes characterization, transport, and disposal in a hazardous waste landfill (including any treatment required by the landfill operator). Therefore, the cost savings to the generator are obvious and significant, and the kiln operator is being paid for a raw material that the cement plant usually has to pay for.

3.3.4.2 Using Solid Waste to Make Cement. Industrial Waste Management in St. Louis, Missouri reports the capability to use metals-contaminated waste as a raw materials substitute in cement making. Candidate raw materials are first analyzed to determine their suitability based on their value and contaminant level. The primary raw materials of interest are silica, calcium, aluminum, and iron. Good candidates for raw materials substitution typically contain 95% or more of these constituents. The company reports that its largest current source for substitute feed is fluidized-bed cracking catalyst.

Systech Resource Recovery Services in Xenia, Ohio accepts nonhazardous wastestreams containing low levels of transition metals as feedstock for cement kilns. Systech has a network of 16 cement kilns to process byproduct materials. Examples of acceptable feed materials include:

Alumina sources:

- catalysts
- ceramics and refractories
- coal ash
- adsorbents for gases and vapors

Calcium sources:

- lime sludges

Iron sources:

- coal slag
- foundry baghouse residuals
- iron mill scale

Silica sources:

- abrasives
- ceramics
- clay filters and sludges
- foundry sand
- sandblast media
- water filtration media

3.3.4.3 Using Spent Fluidized-Bed Cracking Catalyst to Make Cement. A company in Bucaramanga, Colombia has described preliminary testing of spent fluidized-bed catalyst as feed to a cement kiln. The catalyst contains about 60% silica (SiO_2), 33% alumina (Al_2O_3), 1% sodium, 2% iron, 0.03% copper, and 0.05% nickel. The catalyst is used as a replacement for clinker in the final grinding. Tests were performed with 30% and 40% catalyst replacing clinker. The resulting cement was reported to give compressive strength similar to the control cement sample. The catalyst cement set faster and required higher water-to-cement ratios to obtain workability. The authors noted that the high catalyst inputs were used to test the limits of possible additions. Input of catalyst to replace 30% of the clinker would use the annual production of catalyst in 1 week of cement making. Thus, in normal practice, lower quantities of catalyst would be used to produce a more conventional portland cement (Cardenosa et al., 1992).

3.4 Use Spent Abrasive as Concrete Aggregate

This section describes use of spent ABM and similar wastes as a portion of the aggregate in portland cement concrete. The value of ABM used as construction aggregate would be low. The average unit price for construction sand and gravel in 1993 was about \$3.60/ton (free on board [FOB] at the mill) (Tepordei, 1993b). The cost for crushed stone ranges from about \$6.75/ton to \$8.42/ton. The cost for construction sand and gravel ranges from about \$6.73/ton to \$9.84/ton. These costs are current for late 1995 and apply to material delivered to a construction site in truckload quantities (ENR, 1995). The main economic advantage for this option is reduced disposal costs. Use of wastes in asphaltic concrete is described separately (see Section 3.5) due to the different characteristics required for the two different types of aggregate.

3.4.1 Description of Recycling Option

Aggregate is a mineral product from natural or manufactured sources used in concrete making. The specifications for fine and coarse aggregate are described in ASTM 33. The important features of aggregate are size grading; freedom from deleterious materials such as clay lumps, friable particles, and organic materials; and soundness.

The spent ABM could be used to form poured concrete surfaces or concrete blocks or shapes. The cement-making process is illustrated in Figure 3-4. Concrete blocks, bricks, and other shapes are made by combining and forming cement and aggregate. Concrete bricks typically are solid parallelepipeds, whereas blocks have a central opening to reduce weight. A wide variety of specialty shapes also are made from cement and aggregate. Products in this category may be either nonreinforced or reinforced concrete products. Common examples of precast shapes include concrete barriers (New Jersey barriers); precast concrete septic tanks; precast concrete tanks, structures, and cribs; and precast concrete poles. Concrete made by substituting ABM for some of the fine aggregate would be more suitable for applications that do not require high strength such as riprap or fill for protective caissons around bridge pilings (Brabrand and Loehr, 1993).

This recycling technology is straightforward and involves little in the way of operation. Unless the reuse location is on site, the waste aggregate must be transported to the recycler's location. If the aggregate is going to be used as a construction material or as aggregate in concrete, it may be necessary to crush the waste and grade it by particle size. Storage requirements in compliance with any pertinent regulations may involve an impervious liner or bins or hoppers to prevent leaching. Special handling and worker protection also may be required to minimize exposure to dust.

3.4.2 Advantages of Recycling Option

The principal advantages to recycling spent ABM as aggregates are:

- using the spent ABM's favorable structural properties in a beneficial application
- conserving landfill space for the higher hazard waste materials
- reducing waste management cost.

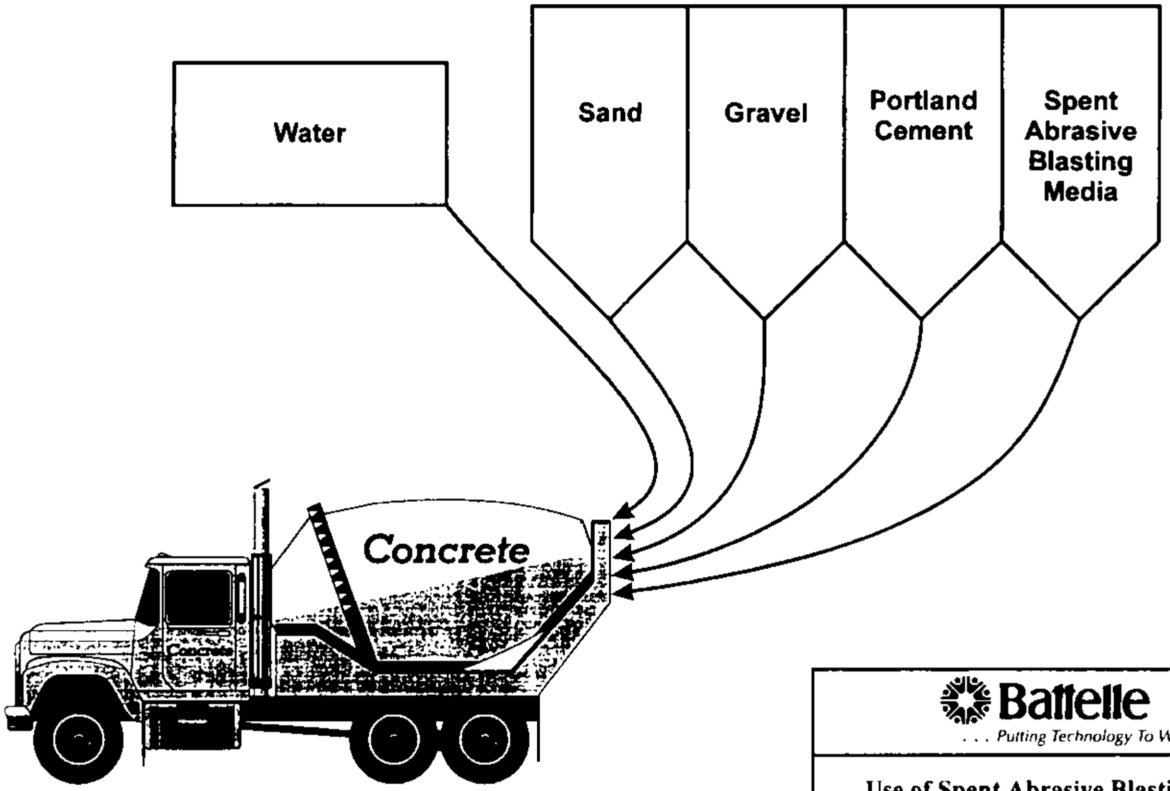
Application of spent ABM as aggregate can recycle large quantities of waste. Also, the use locations are widely distributed throughout the country, so long shipping distances can be avoided in many cases.

3.4.3 Limitations of Recycling Option

Use of spent ABM as a low-value component of a product that often is placed in direct contact with the land may be construed as "use constituting disposal" rather than as a true recycling application. Regulatory agencies responsible for administration of federal and state solid and hazardous wastes should be contacted prior to proceeding with the recycling project. RCRA regulations discourage the land application of recycled hazardous materials (U.S. EPA, 1990c). In most cases special wastes or state-regulated wastes may be recyclable, subject to state or local restrictions or policies. State and local restrictions often are controlled by local agencies such as water quality boards, air quality boards, and local planning commissions. Regulatory considerations are discussed in more detail in Section 4.5.

Use of the spent grit as aggregate chemically and physically immobilizes the contaminants. However, the effectiveness of solidification/stabilization is dependent on the integrity of the cement rather than on fundamental changes in the mineral form of the matrix and contaminant.

Rounded to subangular particle shape is preferred for portland cement concrete aggregate. Spent ABM typically would have more angular particles. Concrete containing a high proportion of spent ABM could have poor mixing, pouring, and setting characteristics (see the first example in Section 3.4.4).



Source: U.S. EPA, 1992

Battelle

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Use of Spent Abrasive Blasting Media in Portland Cement Concrete

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DRAWN BY VS			
CHECKED BY LCG	PROJECT NUMBER G9861-3401	DATE 2/96	

ABM3.CDR

Figure 3-4. Use of Spent Abrasive Blasting Media in Portland Cement Concrete.

The alkali reactivity of the cement and aggregate is an important factor in selecting an aggregate. The concern is reaction of an alkali with the aggregate causing a volume increase and/or loss of concrete strength. The alkali causing the reaction usually is the calcium hydroxide released as cement cures. However, in some cases the alkali may come from external sources such as groundwater. There are two basic types of alkali-aggregate reactions:

- reaction of alkali with siliceous rocks or glasses
- reaction of alkali with dolomite in some carbonate rocks.

Some waste slags can exhibit excessive reactivity. For example, four zinc smelter slag samples tested by Oklahoma State University were found to be unsuitable as aggregate for portland cement due to the excessive expansion during curing caused by alkali aggregate reactions (U.S. EPA, 1990, EPA/530-SW-90-070C).

The alkali activity of a potential aggregate can be determined by one of several tests depending on the type of aggregate to be tested. The applicable tests or guides are ASTM C 227, "Test Method for Potential Alkali Reactivity of Cement-Aggregate Combinations (Mortar-Bar Method)"; C 289, "Potential Reactivity of Aggregates (Chemical Method)"; C 295, "Petrographic Examination of Aggregates for Concrete"; C 342, "Test Methods for Potential Volume Change of Cement-Aggregate Combinations"; and C 586, "Potential Alkali Reactivity of Carbonate Rocks for Concrete Aggregates (Rock Cylinder Method)." Guidance for selecting the appropriate test method is given in C 33, "Standard Specification for Concrete Aggregates."

Waste aggregate used to produce mortar or other cementitious products should have a low metallic aluminum content. Aluminum metal is reactive in the cement paste and corrodes, releasing H_2 gas, causing expansion and decreasing the strength of the cement (Garner et al., 1993).

3.4.4 Example Applications

3.4.4.1 Using Spent ABM as Aggregate in Portland Cement Concrete. Literature was found describing three studies that used spent ABM as aggregate for concrete. The test materials and locations were (1) copper slag used for ship hull blasting in Baharain (Madany et al., 1991), (2) one coal slag and one copper slag used for bridge blasting in Pennsylvania (Weyand and Sutton, 1990), and (3) an unspecified sand from bridge blasting in Texas (Brabrand and Loehr, 1993).

Concentrations of leachable metals exceeded the TCLP limits in some of the unprocessed spent ABM. The Baharain study did not test TCLP leachability. Both the spent coal and copper slag ABM in the Pennsylvania study failed the lead TCLP. In the Texas study, two separate fractions of spent ABM (sand and dust) were collected by vacuum separation. The sand passed the TCLP test but the dust had leachable levels of lead, cadmium, and chromium.

None of the studies noted problems with leachable metals from the final product, but only the Texas study reported TCLP leachability results for the cement product. In the Texas study, metals leachability from both sand and dust materials was significantly reduced by small additions of cement. More cement would be needed to meet strength requirements than would be needed to immobilize the metals.

All of the studies concluded that spent ABM could be used to form low-strength concrete for nonstructural applications. However, in all cases the strength of the product was highly variable and much reduced when ABM was used to replace sand. As a general conclusion, spent ABM is marginally suited as a substitute for the sand portion of concrete aggregate.

3.4.4.2 Aggregate Production from Fly Ash Waste. In the Netherlands, fly ash is sintered to produce a material called Lytag that is suitable as a replacement for sand and gravel in aggregate. The sintering method has four process steps:

- mixing
- pelletizing
- sintering
- final processing

The mixing step combines water and fly ash to produce a paste. The carbon content of the fly ash must be 3% to 5% to provide fuel for the sintering process. If additional carbon is needed, it can be added in the mixing step. The damped powder is formed into pellets and moved by a conveyor.to a hopper, which feeds pellets onto a belt in a layer 11.8 in (30 cm) thick and 6.6 ft (2 m) wide. The belt moves horizontally and passes under an ignition hood where, once inside, the upper surface layer of pellets is ignited. Air is drawn down through the pellets so that the combustion zone moves down through the material on the belt. The combustion process results in a temperature of 2,000°F (1,100°C) that causes the pellets to sinter. In the final production step, any pellets that have sintered together are separated by crushing and are screened to produce three size fractions: 0.02 to 0.16 in (0.5 to 4 mm), 0.16 to 0.32 in (4 to 8 mm), and 0.32 to 0.47 in (8 to 12 mm). Particles over 0.47 in (12 mm) are recrushed, and particles under 0.02 in (0.5 mm) are returned to the process.

The Lytag is reported to have a glassy surface due to sintering and, thus, to be leach resistant. The performance of Lytag as concrete aggregate is reported to be competitive with gravel. Lytag is being used in construction of two large bridges and various industrial and commercial construction projects in the Netherlands (Faase et al., 1991).

3.4.4.3 Aggregate Production from Incinerator Ash. A production process is being developed to remove ferrous and nonferrous metals from incinerator ash, processing the ash to prepare aggregate for concrete. The typical range of ash composition is:

SiO_2	46 to 62%
Fe_2O_3	7.6 to 17%
Al_2O_3	5.5 to 10%
CaO	8.0 to 14%
Na_2O	3.6 to 7%
MgO	1.0 to 2%
SO_3	0.4 to 2%

The ash passes through a series of crushers, screens, and magnetic separators to remove metals. The ash is first crushed with a jaw crusher and then passed through roll crushers. Ferrous metals are removed by magnetic separators. The roll crushers flatten the softer nonferrous metal particles into platelets. Ash leaving the roll crushers is screened with a 0.9-mm (0.035-inch) sieve. The metal platelets are retained while the mineral matter passes through the screen. The mineral residues are further crushed to pass through a 0.01-in (0.3-mm) sieve. The residues are blended with clay, pelletized, and fired in a rotary kiln to produce smooth spherical aggregate. The resulting aggregate has undergone testing in concrete for up to 4.5 years (Wainwright and Robery, 1991).

3.5 Use Spent Abrasive as Asphalt

This section describes the use of spent ABM and similar wastes as a portion of the aggregate in asphaltic concrete. The value of ABM used as construction aggregate would be low. The average unit price for construction sand and gravel in 1993 was about $3.60/ton (FOB at the mill) (Tepordei, 1993b). The cost for crushed stone ranges from about $6.75/ton to $8.42/ton. The cost for construction sand and gravel ranges from about $6.73/ton to $9.84/ton. These costs are current for late 1995 and apply to material delivered to a construction site in truckload quantities (ENR, 1995). The main economic advantage for this option is reduced disposal costs. Use of wastes in portland cement concrete is described separately (see Section 3.4) due to the different characteristics required for the two different types of aggregate.

3.5.1 Description of Recycling Option

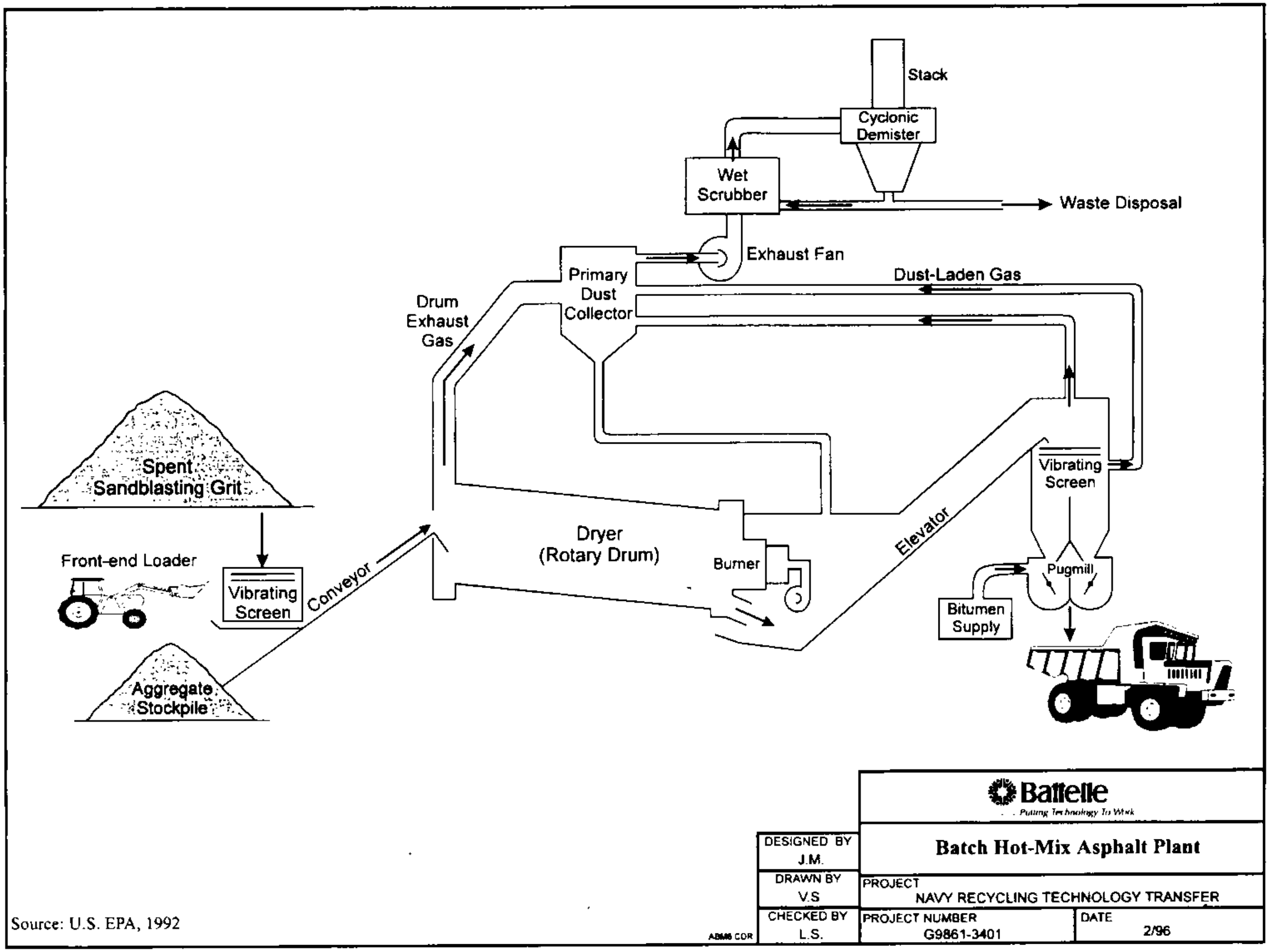
The recycling of wastes into asphaltic concrete is not a particularly new concept. A wide variety of materials have been successfully substituted for some portion of the normal graded aggregate without adverse effects on product quality. The hot mix process for asphalt production is illustrated in Figure 3-5. The most widespread example of waste used as aggregate in asphaltic concrete is reuse of reclaimed asphaltic concrete from previous paving projects. Old asphalt paving is crushed and substituted for a portion of the aggregate in either cold mix or hot mix asphaltic concrete. More than 12,000,000 tons (10,900,000 metric tons) of asphalt were recycled by 35 asphalt contractors in 1992 (ARRA, 1994). The corresponding savings were over $600 million in landfill costs and over $30 million for liquid asphalt and aggregate. In certain situations, the old pavement is recycled into cold or hot mix asphalt in place, thereby reducing paving costs and reducing truck traffic on the highways to transport the old aggregate back to the contractor's facility (ARRA, 1994).

Another example of waste recycling into asphalt is the recently developed concept of using glass cullet as an aggregate in asphalt. The resulting product has been termed "glassphalt" (Monroe, 1990). Glassphalt uses mixed color glass which has low value in the conventional glass recycling market. Glassphalt containing 10% glass was used in a base course lift for the first time on a project in New Jersey. Highway agencies in Connecticut, District of Columbia, New Jersey, and Virginia have been using glassphalt on a trial basis (Ahmed, 1993).

The ABM-to-asphalt recycling technology involves simply substituting the ABM for a portion of the fine-size aggregate in asphaltic concrete. As long as the metal concentrations in the spent ABM are not excessively high, the metal concentrations in the asphaltic concrete product will be very low, and any metals present will be physically and chemically immobilized in the asphalt binder. Typically, asphaltic concrete consists of 4.5 to 8% bitumen mixed with graded aggregate. The aggregate is made by mixing rock and sand to give particles ranging from fine sand to 1/2- to 1-in (13-mm to 25-mm) gravel. Depending on the mix design and the ultimate strength requirements of the product, the fine-size particle fraction may comprise 35 to 45% of the asphaltic concrete.

3.5.2 Advantages of Recycling Option

Application of spent ABM as aggregate can recycle large quantities of waste. Also, the use locations are widely distributed throughout the country so long shipping distances can be avoided in many cases.



Source: U.S. EPA, 1992

Figure 3-5. Illustration of the Hot-Mix Process for Asphalt Making.

Applicable wastes include a wide variety of geologic materials, pavement, construction materials, ceramics, or glasses that are either aggregates or can be crushed to form aggregates. Because reuse usually is in the public domain, the wastes should contain only low levels of relatively low-hazard contaminants. The technology for reusing nonhazardous soil and sand wastes for asphalt aggregate is mature and commercially available. Oil-contaminated soil has been used as asphalt aggregate in construction projects for many years (U.S. EPA, 1992, EPA/600/R-92/096).

Sharp angular particle shape is preferred for asphaltic concrete aggregate. Spent ABM typically would have more angular particles and should provide a good substitute for the sand portion of asphalt aggregate.

3.5.3 Limitations of Recycling Option

The asphalt recycling approach is viable only for certain types of aggregates. The aggregate must comply with both performance and environmental standards such as durability, stability, chemical resistance, biological resistance, permeability, and leachability (Testa and Patton, 1994). The principal limitations pertain to risk, regulatory considerations, or technical considerations pertaining to the integrity of the asphaltic concrete product. For example:

- ABM containing solvents or other particularly hazardous or toxic constituents should not be recycled in this manner.

- ABM with high metal contents (percent level or greater) may pose hazards either to workers at the asphalt plant due to dust exposure or to the public through the asphalt product because of metals leaching.

- The presence of sulfate or metallic iron is undesirable because of swelling upon oxidation. Reduced forms of trace metals may cause similar problems, which, however, may be avoidable by recycling the ABM into a base course layer where there is minimal contact with air.

- High concentrations of silt and smaller size particles are undesirable because they have poor wetting characteristics in the bitumen matrix and may generate dusts.

- Rounded aggregates do not give good vehicle traction characteristics when used in asphaltic concrete.

The chief chemist or engineer at the asphalt plant must ensure that the ABM is compatible with the production of a high-integrity asphaltic concrete.

Use of spent ABM as a low-value component of a product that is placed in direct contact with the land may be construed as "use constituting disposal" rather than a true recycling application. Regulatory agencies responsible for administration of federal and state solid and hazardous wastes should be contacted prior to proceeding with the recycling project. RCRA regulations discourage the land application of recycled hazardous materials (U.S. EPA, 1990c). In most cases, special wastes or state-regulated wastes may be recyclable, subject to state/local restrictions or policies. State and local restrictions often are controlled by local agencies such as water quality boards, air quality boards, and local planning commissions. Regulatory considerations are discussed in more detail in Section 4.5.

Use of the spent grit as aggregate provides chemical and physical immobilization of contaminants. However, the effectiveness of solidification/stabilization is dependent on the integrity of the asphaltic concrete rather than on fundamental changes in the mineral form of the matrix and contaminant.

3.5.4 Example Applications

3.5.4.1 Using Spent ABM as Aggregate in Asphaltic Concrete. The NFESC in Port Hueneme, California has been studying the recycling of spent ABM in the form of sandblasting grit into asphaltic concrete for commercial paving purposes. The sandblasting grit is used as a "blender sand" for a portion of the fine-grained aggregate that is used to produce the asphaltic concrete. This section briefly describes the case history for the ongoing "ABM-to-asphalt" recycling project in Hunters Point, California.

The spent ABM at Hunters Point is comprised of a 4,000-yd^3 (3,060-m^3) pile of Monterrey Beach sand contaminated with small amounts of paint chips. The spent ABM was generated in ship-cleaning operations conducted at Naval Station, Treasure Island, Hunters Point Annex by Triple AAA Shipcleaning during the 1970s and 1980s. Average copper, zinc, lead, and chromium concentrations are 1,800, 1,100, 200, and 100 mg/kg, respectively. Leachable metals concentrations using the California Waste Extraction Test (WET) methodology average 140, 150, 20, and 2.0 mg/L, respectively for copper, zinc, lead, and chromium. The WET test is California's version of the RCRA TCLP. The spent ABM at Hunters Point is considered hazardous by the state because of Soluble Limit Threshold Concentration (STLC) exceedances on the WET test for copper and lead, but is not an RCRA-listed hazardous waste because it passes the TCLP.

In the ABM-to-asphalt technology demonstration at Hunters Point, an ABM concentration of 5% by weight of the final asphaltic concrete is being used so the spent ABM comprises 5% of the asphaltic concrete replacing about 1/9 to 1/7 of the normal sand portion of the concrete. Higher ABM contents are possible; theoretically the entire fine fraction of the mix design could be comprised of ABM. However, at higher ABM concentrations, there is greater potential for lower product quality or elevated leachable metals concentrations in the product.

At Hunters Point the ABM is being recycled into hot mix asphalt for normal commercial paving applications, yielding high-strength asphaltic concrete for heavily used highways. ABM can be recycled into both a base course layer or any subsequent lifts applied to the base course. ABM also can be recycled into cold mix processes, which yield a lower grade product for road repair or lower traffic area applications.

The cost of an ABM-to-asphalt recycling project will depend on a number of factors, particularly:

- tippage rate charged by the asphalt plant
- distance between the generator and the asphalt plant, which affects transportation costs
- required amount of planning, regulatory interactions, reporting, and program management

and to a lesser extent:

- analytical fees for chemical and physical analyses of asphalt test cores to show compliance with any regulatory or institutional requirements
- ABM pretreatment such as screening and debris disposal

In the Hunters Point project, the tippage rate charged by the asphalt plant is $40/ton of ABM recycled. The overall unit cost about $140/ton, including significant costs for transportation to the asphalt plant, regulatory compliance, and analytical testing of core specimens produced in the laboratory prior to full-scale recycling. In general, the recycling unit cost decreases with increasing amounts of spent ABM recycled. The following ranges are typical for most projects:

Amount ABM (tons)	Estimated Costs of Recycling (per ton)
500 - 1,500	$125 - $175
1,500 - 3,000	$100 - $150
3,000 - 6,000	$ 50 - $100

Therefore, economically, the ABM-to-asphalt recycling approach is a win-win situation for both the asphalt plant and the ABM generator. Recycling costs the generator less per ton than the cost for disposal in a hazardous waste landfill and probably less than it would cost for on-site treatment and disposal, and the asphalt plant is paid for a raw material that it ordinarily would have to buy.

3.5.4.2 Using Soil as Aggregate in Asphaltic Concrete. A review of the literature found two examples of application of metal-contaminated soils as asphalt aggregate. American Reclamation Corporation asphalt was used to stabilize soil contaminated with fuel oil and lead at a closed steel wire manufacturing plant. The contaminants reportedly were immobilized by the asphalt treatment, allowing the material to be used to pave the site after remediation was completed.

Applied Environmental Services treated soil from a railcar brake shoe manufacturing plant containing 438 mg/kg lead and 336 mg/kg zinc. The soil was excavated and treated off site at a cold mix asphalt plant. Treatment was reported to have achieved acceptable immobilization of the metals. The treated waste was returned to the site for use as paving (Testa and Patton, 1992).

3.5.4.3 Using Steel Shot as Aggregate in Asphaltic Concrete. The incorporation of steel shot ABM from bridge-blasting operations has been the subject of an ongoing demonstration project in North Carolina (Medford, 1989, 1990, and 1992). Recent results suggest that the steel shot ABM is not compatible with the asphaltic concrete product and is leading to premature failure due to the oxidation and swelling of the steel particles (Medford, 1992, personal communication).

3.5.4.4 Using Spent Foundry Sand as Aggregate in Asphaltic Concrete. Lead-contaminated foundry sands from brass foundries in Pennsylvania are being recycled into asphalt (Boyd, 1992).

3.6 Use Spent Abrasive as a Construction Material

This section describes using spent ABM or similar wastes as replacements for construction materials. Minimal preprocessing may be done to remove debris or reduce metal leachability. If the waste has high organic content, high leachable metal content, low strength, a high proportion of fines, or other undesirable properties, more aggressive processing may be needed to produce a usable product (see Section 3.7).

Crushed stone, sand, and gravel fill a wide range of needs in the construction, chemical feedstock, and other industries. The quantities used are enormous. For example, the estimated crushed stone production in the United States during the second quarter of 1995 was 367,500,000 tons (333,600,000 metric tons). The estimated production of construction sand and gravel in the United States during the second quarter of 1995 was 265,100,000 tons (240,700,000 metric tons) (Tepordei, 1995). The average unit price for construction sand and gravel in 1993 was about $3.60/ton (FOB at the mill) (Tepordei, 1993b). The cost for crushed stone ranges from about $6.75/ton to $8.42/ton. The cost for construction sand and gravel ranges from about $6.73/ton to $9.84/ton. These costs are current for late 1995 and apply to material delivered to a construction site in truckload quantities (ENR, 1995).

3.6.1 Description of Recycling Option

Sand and gravel are granular, unconsolidated agglomerations of rocks and minerals produced mainly by natural breakdown and abrasion of rocks (Bolen, 1993). The ASTM defines sand as naturally occurring unconsolidated or poorly consolidated rock particles that pass through a Number 4-mesh U.S. standard sieve and are retained on a Number 200-mesh U.S. standard sieve. Gravel is defined as naturally occurring unconsolidated or poorly consolidated rock particles that pass through a sieve with 3-in (7.62-cm)-square openings and are retained on a Number 4-mesh U.S. standard sieve. The construction industry generally accepts this differentiation of sand and gravel based on particle size.

Sand and gravel consist of a variety of rock and mineral types, so the composition varies. Silica is the major component of most commercial sand and gravel. Feldspar, mica, and iron oxides are common minor constituents. Specifications for sand and gravel used in roadbed and concrete construction usually state strict particle size gradation and shape requirements. Other requirements with regard to physical and chemical properties may be stated depending on the soil conditions, climate, and other locality-specific conditions. The National Aggregates Association has compiled 42 ASTM specifications and test methods for aggregates, concrete, and admixtures (Tepordei, 1993a).

The ASTM and the American Association of State Highway and Transportation Officials (AASHTO) are the main national organizations setting specifications on crushed stone for use in construction (Tepordei, 1993b). However, many specifications for construction aggregates are developed by states or localities based on their specific needs. Most common specifications control size grades, soundness, shape, abrasion resistance, porosity, chemical compatibility, and content of soft particles. Due to the skid resistance imparted to road surfaces when blast furnace or steel furnace slag is used as the aggregate, many state agencies specify slag aggregate for asphalt used for roads with high traffic volume (Solomon, 1993).

The American Railroad Engineering Association sets standards for railroad ballast. The general characteristics required of a good ballast material are strength, toughness, durability, stability, drainability, cleanability, workability, and resistance to deformation.

3.6.2 Advantages of Recycling Option

Application of spent ABM in general construction can recycle large quantities of waste. Also, the use locations are widely distributed throughout the country so long shipping distances can be avoided in many cases.

When the physical and chemical characteristics allow the waste to be reused directly in a construction application, the processing is simple and uses commercially available equipment. Figure 3-6 illustrates one way of using spent ABM for contained fill. There is a well-established precedent for recycling waste materials with characteristics similar to spent ABM in the construction industry. In 1994, an estimated 19 million metric tons of iron and steel slags, with an approximate value of $130,000,000, were recycled. About 80% of the recycled slags are used in construction applications such as road base, asphalt or cement aggregate, and fill. Other applications such as mineral wool manufacture, soil conditioning, and roofing account for the other 20% of slag use (Solomon, 1995b). Other ore-processing slags have been applied as drainage material in landfill construction and railroad road beds (U.S. EPA, 1990d, EPA/530-SW-90-070C). Spent foundry sand is another potential material for use in construction as road fill, aggregate, or daily landfill cover. About 6 million tons of spent foundry sand are produced annually by U.S. foundries, of which only 4.2% is put to beneficial reuse (Smith, 1992).

3.6.3 Limitations of Recycling Option

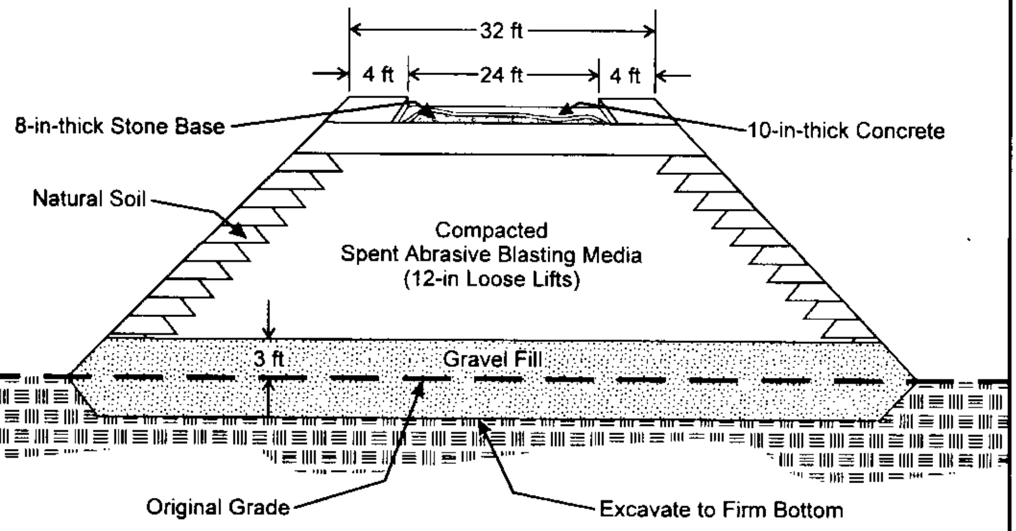
The principal requirements for the use of waste materials as aggregates or bulk materials are (1) acceptance by regulatory agencies, the customer, and the affected public; and (2) performance. Typically, the waste material must lend some useful function to the product and meet some leach-resistance criteria and specifications for physical properties (Wisconsin Department of Natural Resources, 1993). The end use should not be simply disposal in another form (termed "use constituting disposal" or "sham recycling"). Even if regulatory requirements and technical specifications are met, there may be reluctance on the part of the customer or the public to accept the use of those materials.

Wide use of waste materials for construction applications may pose the risk or perceived risk of exposing a large population to hazardous materials, generating occupational and public health concerns. The two principal exposure pathways are through inhalation of dusts or leaching of soluble metals from the aggregate into groundwater or surface water. Any recycling project using spent ABM in construction must have documented, quantitative evidence that no significant risk is being added to either the process or the product. Test results should demonstrate negligible incremental risk to the occupational workforce or to the public during processing of the material in its reuse environment. Potential liabilities may exist for the waste generator for real or perceived health effects resulting from the reuse.

The recycled material must equal or exceed the performance of the raw material it will replace. Product specifications for construction material include strength, size grading, chemical composition and purity, and chemical reactivity.

3.6.4 Example Applications

3.6.4.1 Using Ash in Construction Applications. Ash from a refuse-to-energy facility for processing of municipal waste is treated and used for landfill road construction. About 10 to 12% portland Type II cement is added to the ash. The treated ash is formed and cured to give a monolith which is crushed by equipment at the landfill. The resulting particulate is used as a subbase material for asphalt roadways at the landfill. The treated ash is accepted at no charge by the landfill and replaces recycled asphalt subbase that previously cost the landfill $2/ton (Korn and Huitric, 1992).



NOT TO SCALE

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Typical Cross Section Showing Use of Spent Abrasive Blasting Media as Fill

DESIGNED BY LS			
DRAWN BY VS	PROJECT NAVY RECYCLING TECHNOLOGY TRANSFER		
CHECKED BY LCG	PROJECT NUMBER G9861-3401	DATE 2/96	

Source: Ahmed, 1993

ABM6 CDR

Figure 3-6. Typical Cross Section Showing Use of Spent Abrasive Blasting Media as Fill.

3.6.4.2 Beneficial Reuse of Foundry Sand. Foundry sand has been used extensively in construction applications. More complex sand and binder systems and increased concern over potential chemical hazards have resulted in a decline of such use in recent years. The Wisconsin Department of Natural Resources is developing a program to encourage responsible beneficial reuse of foundry byproducts. In particular, the state is developing fact sheets for beneficial reuse of foundry sand in applications such as these (Wisconsin DNR, 1993):

- foundation subgrade fill
- concrete and asphalt fine aggregate
- landfill daily cover
- pavement subbase fill
- contained embankment fill

3.6.4.3 Soil Recycling Demonstration. The Toronto Harbor Commissioner's soil recycling process produces reusable fill material by treating soils using a three-step process to remove organic and inorganic contaminants to produce a reusable fill material. First, soil washing reduces the volume of material to be treated by concentrating the contaminants in a fine slurry. The second step removes metals from the slurry by acidification and chelation. In the third step, chemical hydrolysis and biodegradation destroy organic contaminants concentrated in the slurry. The technology is reported to produce clean soil for reuse as fill material. A Superfund Innovative Technology Evaluation Program Demonstration took place in April and May of 1992 (U.S. Environmental Protection Agency, 1993, EPA/540/AR-93/517).

3.7 Vitrify Spent Abrasive to Form Construction Material

This section describes high-temperature processing to convert spent ABM or other wastes with a high silica content to low-value construction materials. Vitrification will destroy organic contaminants, reduce leachability of metals, and make a product with high compressive strength and a controlled particle size distribution. Thus, vitrification can be used to convert wastes with undesirable chemical and physical properties into a useful product. Thermal processing to produce high-value ceramic products is discussed in Section 3.2.

3.7.1 Description of Recycling Option

Waste vitrification is a thermal treatment technology that oxidizes, melts, and transforms a broad spectrum of wastes into a glasslike or rocklike material. The average composition of the earth's crust is compared to the composition of several glass formulations in Table 3-3. The similarity of the compositions indicates that mineral processing slags and minerals, such as those used to manufacture ABM, would be expected to be good candidates for vitrification.

Vitrification is accomplished by introducing the waste into a melting kiln or container where the waste is heated to form a liquid melt. A typical overall mass balance for vitrification using a plasma arc heat source in a reducing environment is shown in Figure 3-7.

The melting energy is derived from the oxidation of materials in the feed and from external heating of the waste material. Electrical conduction through the molten waste and plasma arc heating are two common methods for heat input. Some systems use fossil fuel heating, which reduces energy costs but increases the volume of off-gas generated.

Table 3-3. Comparison of the Earth's Crust to Common Commercial Glasses

Oxide Material	Average Composition of the Earth's Crust (wt%)	Typical Composition of Soda-Lime Glass (wt%)	Typical Composition of Borosilicate Glass (wt%)
SiO_2	59.7	73.3	80.4
Al_2O_3	15.5	1.5	2.3
Fe_2O_3	7.2	0.1	0.0
CaO	5.1	9.8	0.0
Na_2O	3.8	14.2	3.8
MgO	3.5	0.3	0.0
K_2O	3.1	0.6	0.6
SO_3	0.1	0.2	0.0
Cl	0.1	0.0	0.0
B_2O_3	Trace	0.0	12.9

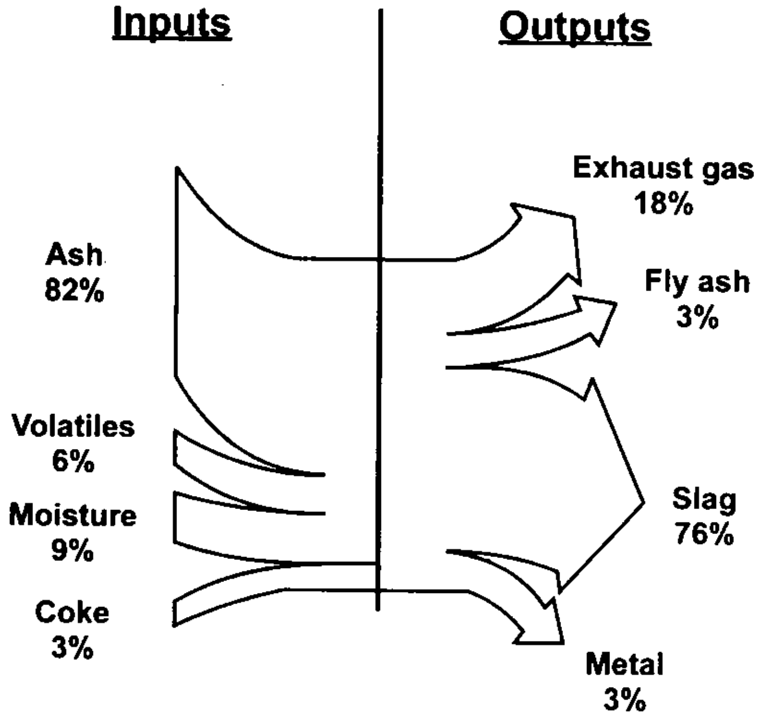
The discharged product usually provides high-volume reduction and a chemically durable material that typically passes the TCLP test as nonhazardous. The process typically collects particulates in the off-gas system and returns them to the melter feed to minimize secondary waste generation. For nonhazardous wastes, the discharged glass can be formed into useful construction materials, such as artificial aggregate, erosion-control boulders or slabs, or clean fill. Reuse of treated characteristic waste is possible (see Section 4.5.1 for a definition of hazardous characteristic). Testing will be required to demonstrate that the vitrification process removed the hazardous characteristic. However, it will be more difficult to identify markets of a material due to the previous waste code.

3.7.2 Advantages of Recycling Option

Vitrification of waste materials may be achieved over a broad range of earth and waste compositions and can immobilize many metal contaminants. The approximate solubility limit of a variety of common metal contaminants in glass is shown in Table 3-4 to indicate the general types and concentrations of metal contaminants that can be immobilized in a vitrified waste product. Examples of suitable wastes include sludge from wastewater treatment, electric arc furnace off-gas treatment residues, and baghouse dust (U.S. Air Force, 1990).

Vitrification has been adopted as the Best Demonstrated Available Technology (BDAT) for high-level radioactive wastes and for nonwastewater arsenic wastes. However, pretreatment usually is required to control arsenic volatilization during the vitrification process (U.S. EPA, 1990a, EPA/530/SW-90/059A).

The high-temperature vitrification process causes significant changes in the physical and chemical form of the matrix and the contaminants. Organic contaminants are oxidized to their mineral components. Metal contaminants are incorporated into a durable, leach-resistant mineral matrix. The discharged product is a chemically durable material that typically passes the TCLP test as nonhazardous. The process provides volume reduction (40% for soils to >99% for combustibles) (U.S. EPA, 1991, EPA/600/2-91/041).



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Material Balance for a
Typical Plasma Arc
Vitrification System

DESIGNED BY LS			
DRAWN BY VS	PROJECT NAVY RECYCLING TECHNOLOGY TRANSFER		
CHECKED BY LCG	PROJECT NUMBER G9861-3401	DATE 2/96	

Source: Inaba, 1995

ABMS CDR

Figure 3-7. Material Balance for a Typical Plasma Arc Vitrification System.

Table 3-4. Approximate Solubility Limit of Oxides of Metals in Silicate Glass

Element	Maximum Allowed Oxide Content (%)	Element	Maximum Allowed Oxide Content (%)
Ag	0.1	Mg	30
As	5	Mn	10
B	20	Mo	2
Ba	15	Ni	5
Be	10	Pb	30
Cd	1	Sb	2
Co	2	Se	1
Cr	2	Sn	5
Cs	25	Sr	15
Cu	5	U	20
Ga	5	Y	1
Hg	0	Zn	20

3.7.3 Limitations of Recycling Option

The vitrification process is capital and energy intensive. Processing is unlikely to break even for wastestreams when forming a low-value construction material. The main economic advantage is avoided disposal costs.

The construction material made by vitrification of spent ABM often will be placed in direct contact with the land. Even though significant chemical and physical changes occur during vitrification, use of vitrified wastes may be construed as "use constituting disposal" rather than a true recycling application. Regulatory agencies responsible for administration of federal and state solid and hazardous wastes should be contacted prior to proceeding with the recycling project. RCRA regulations discourage the land application of recycled hazardous materials (U.S. EPA, 1990c). In most cases special wastes or state-regulated wastes may be recyclable, subject to state or local restrictions/policies. State and local restrictions often are controlled by local agencies such as water quality boards, air quality boards, and local planning commissions. Regulatory considerations are discussed in more detail in Section 4.5.

Volatile metals such as arsenic, mercury, or beryllium are difficult to treat and can be present only at low concentrations. Wastes containing arsenic will require some combination of pretreatment, special processing conditions, and off-gas treatment systems to minimize arsenic volatilization. If reducing conditions can occur in the melt, cadmium, lead, and zinc can vaporize and enter the off-gas stream (Hollander et al., 1995).

3.7.4 Example Applications

3.7.4.1 Vitrification of Nonhazardous Sludge. World EnviroTech in New York, New York designs, builds, and operates thermal treatment systems to convert nonhazardous wastes such as sewage sludge to aggregate. The primary processing chamber operates at 2,400°F (1,300°C). Waste material reportedly is converted to an environmentally stable solid. The product can be either granulated (to a mainly vitreous form) or air-cooled (to a rocklike form) and is suitable for a wide range of uses as a replacement for sand and gravel. Example uses include preparing a subbase for roads, mixing in concrete as aggregate, or backfilling a pipe trench.

3.7.4.2 Waste Vitrification Process Options. Waste vitrification systems are under development or are available for hazardous and nonhazardous wastes from several vendors. Some examples of waste systems are summarized in Table 3-5.

Table 3-5. Examples of Some Waste Vitrification Process

Company/Process Name	Location	Process
Allis Mineral Systems/ Pyrokiln Encapsulation	20965 Crossroads Circle Waukesha, WI (414) 798-6265; fax (414) 798-6211	Fossil-fueled, direct-fired slagging rotary kiln(b)
Ausmelt	1331 17th Street, Suite M103 Denver, CO 80202 (303) 295-2216; fax (303) 295-7605	Fossil-fueled, direct-fired lance heater(c)
Babcock and Wilcox/ Cyclone Furnace	2200 Langhorne Drive Alliance, OH (216) 829-7394; fax (216) 829-7801	Fossil-fueled, direct-fired vortex furnace(a)(b)
Battelle/Terra-Vit	Battelle Boulevard, P.O. Box 999 Mail Stop P7-41 Richland, WA 99352 (509) 376-6576	Joule-heated melter(a)
Ecotechniek/Ecogrind	Het Kwadrant 1 Maarssen, 3606 The Netherlands (31-465) 577-00; fax (31-465) 544-72	Sintering in a rotary kiln(a)
EET Corporation/Microwaste Solidification Technology	129A Perimeter Park Road Knoxville, TN 37922 (615) 691-1223; fax (615) 691-2656	Microwave heating in drum(a)
Electro-Pyrolysis Inc./ Electro-Pyrolysis	996 Old Eagle School Road, Suite 1118 Wayne, PA 19087 (215) 687-9070; fax (215) 964-8570	Direct-current arc furnace(a)
EM&C Engineering Associates/ Vitriflux	1665 Scenic Avenue, Suite 104 Costa Mesa, CA 92626 (714) 957-6429; fax (714) 957-6414	Vitrification at low temperature using flux addition(a)
ENVITCO, Inc.	8400 West Central Avenue Sylvania, OH 43560 (419) 829-2728; fax (419) 537-1369	Small-batch, joule-heated melter(c)

Table 3-5. Examples of Some Waste Vitrification Process Vendors (Continued)

Company/Process Name	Location	Process
Ferro Corporation/ Waste Vitrifier	7500 East Pleasant Valley Road Independence, OH	Joule-heated melter[b]
Multiplex Environmental/ Xtaltite	4570 Westgrove Drive, Suite 255 Addison, TX 75248 (214) 733-3378; fax (214)733-0366	Combination of hydrometallurgical and pyrometallurgical processing to convert waste to a stable mineral form[a]
Penburthy Electromelt International, Inc.	631 South 96th Seattle, WA 98108 (206) 762-4244; fax (206) 763-9331	Joule-heated melter[c]
Plasma Technology Corporation/ Plasma Pyrolysis and Vitrification	8601 Six Forks Road, Suite 400 Raleigh, NC 27615 (919) 676-5304; fax (919) 676-5305	Plasma arc[c]
Retech/ Plasma Arc Centrifugal Treatment	100 Henry Station Road Ukiah, CA 95482 (707) 462-6522; fax (707) 462-4103	Plasma arc-heated rotating tub (centrifugal) melter[a][b]
Stir-Melter/ STIR-MELTER Systems	Ampoint Industrial Park 995 Fourth Street Perrysburg, OH 43552 (419) 536-8828; fax (419) 536-8288	Joule-heated, stirred melter[a]
Vortec Corporation/ Combustion and Melting System	3770 Ridge Pike Collegeville, PA 19426 (610) 489-2255; fax (610) 489-3185	Fossil-fueled, direct-fired vortex furnace[a][b]
Western Product Recovery Group, Inc./Coordinate Chemical Bonding and Adsorption	P.O. Box 79728 Houston, TX 77279 (713) 493-9321; fax (713) 493-9434	Sintering and partial slagging in a direct-fired rotary kiln[b]
Westinghouse Electric Corporation Science and Technology Center	1310 Beulah Road Pittsburgh, PA 15235 (412) 256-2235; fax (412) 256-1948	Plasma arc[c]

Sources:

(a) VISITT Version 4.0 (U.S. EPA, 1995, EPA/542-C-95/001).

(b) U.S. EPA, 1994, EPA/540/R-94/526.

(c) Vendor literature.

3.8 Processing in a Smelter

The metal content of spent ABM will not be sufficiently high to justify smelting to recover metals. The silica and calcium content may be useful as required slag-forming elements so that the spent ABM can be reused as flux in a pyrometallurgical process.

3.8.1 Description of Recycling Option

Pyrometallurgy is a broad term covering techniques for processing metal-bearing ores at elevated temperature. Processing at elevated temperature increases the rate of reaction and reduces the reactor volume per unit output. Elevated temperature often makes the reaction equilibrium more favorable. Pyrometallurgy, the oldest type of extractive metallurgy, dates back to the origins of recovering useful metals from ore. The earliest recorded use of pyrometallurgy was conversion of copper oxide ores to copper metal by heating with charcoal. This early type of pyrometallurgy was well established by 3,000 BC.

Pyrometallurgical processing to convert metal compounds to elemental metal usually requires a reducing agent, fluxing agents to facilitate melting and to slag off impurities, and a heat source. Figure 3-8 shows examples of oxidation and reduction smelting. The fluxing agents form a eutectic or other low-melting-point material due to the chemistry of the melt. An acceptable melting point is achieved by adding fluxing agents such as calcium oxide or by appropriate blending of the feedstocks. The most common fluxing agents in mineral smelting are silica and limestone. The spent ABM could be used to replace mineral raw materials as a source of silica. The spent ABM may contain trace metals that are recovered by the smelter, but the quantities would be incidental. The main recycling benefit from the ABM would be to provide silica.

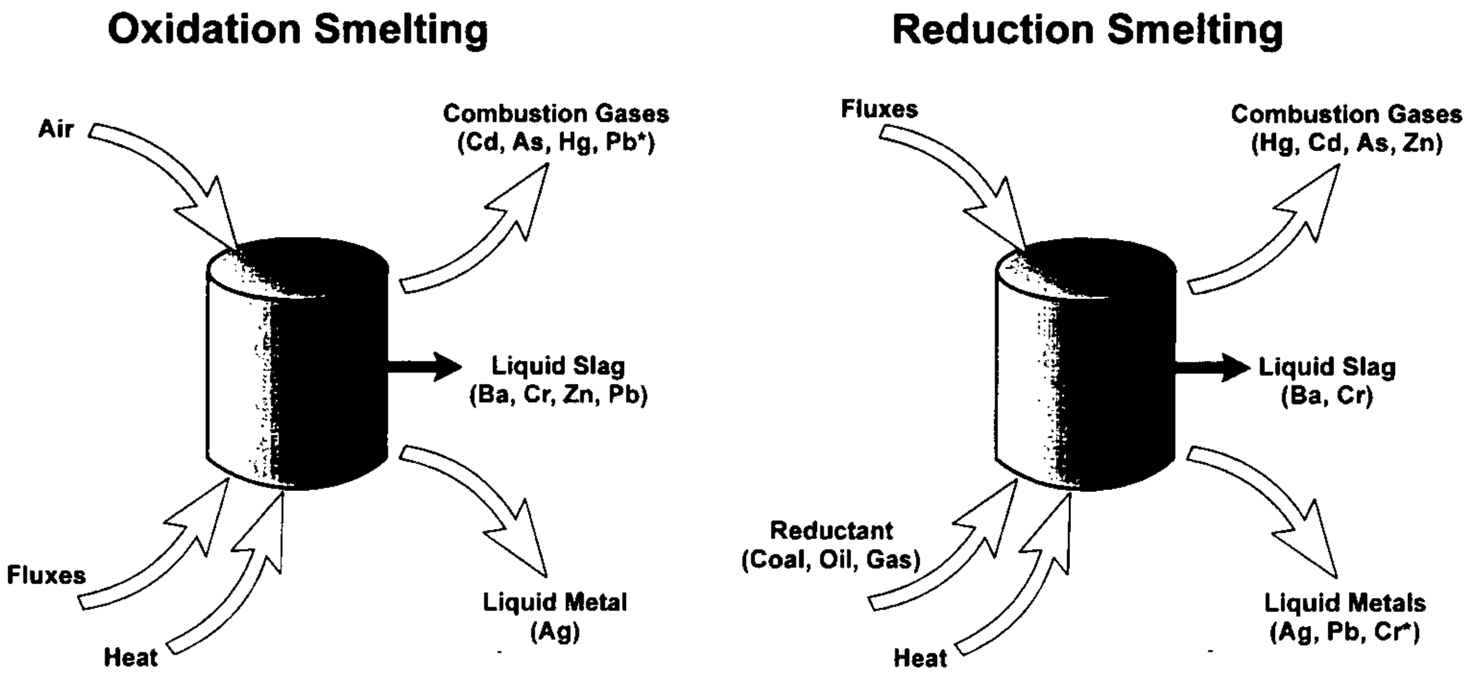
Separating the metal from the undesirable waste components typically is accomplished by physical action based on phase separations. As the metal salts react with the reducing agent to form metal or matte, the nonmetallic portions of the ore combine with the flux to form a slag. Volatile metals such as zinc and cadmium vaporize and are collected by condensation or oxidation from the off-gas, usually as oxides due to combustion of metal fume in the flue. Dense, nonvolatile metals can be separated from the less dense silicate slag by gravity-draining the metallics from the bottom of the reaction vessel. Slag oxides are tapped from a more elevated taphole.

3.8.2 Advantages of Recycling Option

Using spent ABM or other high-silica wastes in a smelter offsets the consumption of rock while producing a leach-resistant slag. The slag is similar to the product made by vitrification (see Sections 3.2 and 3.7). Using the waste in a smelter takes advantage of existing equipment to avoid the high capital and operating cost of a vitrification unit.

3.8.3 Limitation of Recycling Option

The slag chemistry in a smelting furnace must be closely controlled to produce a low-melting mix that scavenges impurities and helps to chemically reduce metal salts in the ore to elemental metal. Silicon and calcium compounds are desirable in helping to form a slag with the correct melting point. High-melting oxides such as alumina are undesirable. The smelter operators will be required to frequently sample and analyze the wastes to ensure they are compatible with the slag chemistry.



*If temperature is sufficiently high (1,400-1,600°C), Pb will volatilize as PbO.

*Chromium will distribute between metal and slag.

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Examples of Smelting Processes

DESIGNED BY LS			
DRAWN BY VS	PROJECT NAVY RECYCLING TECHNOLOGY TRANSFER		
CHECKED BY LCG	PROJECT NUMBER G9861-3401	DATE 2/96	

ABM7.CDR

Figure 3-8. Examples of Smelting Processes.

3.8.4 Example Applications

3.8.4.1 Using Ash in Copper Smelting. Cyprus Miami Mining in Claypool, Arizona is a primary copper smelter used to process complex sulfide ores (LaChappelle and Dyas, 1993). The smelter produces copper as its main product with a small, but valuable, byproduct stream of gold and silver. Volatile metals such as lead, arsenic, and mercury are captured by acid scrubbing and sent to other facilities for recovery. The company is reported to be an exempt recycling facility with the capability of accepting D002 through D011 characteristic waste and F006 listed waste. The facility accepts selected metals; metal sludges or filter cakes; and incinerated ashes containing copper, silver, or gold. Processing ash from incineration of municipal wastewater treatment sludge provides silica as a flux and allows recovery of the trace quantities of gold and silver in the sludge. The plant also processes used foundry sand and lime residues from boiler cleaning. These materials provide fluxing agents and allow metal recovery.

3.8.4.2 Smelting Lead-Containing Wastes. The Center for Hazardous Materials Research and Exide/General Battery Corporation are demonstrating the use of secondary lead smelting to reclaim usable lead from waste materials containing between 1 and 50% lead. The characteristics of secondary lead smelters in the United States are summarized in Table 3-6. Waste containing 1 to 25% lead is treated in a reverberatory furnace to produce slag containing about 70% lead. The slag and other high-lead-content materials are fed to a blast furnace to produce lead metal products. Testing as part of the Superfund Innovative Technology Evaluation (SITE) Program has been performed on a variety of waste materials including battery cases, slags, lead dross, and lead paint chips. Materials from Superfund or other contaminated sites could be mixed with other higher grade lead material for smelting. The reported treatment cost ranges from $150/ton to $250/ton for Superfund materials (Timm and Elliott, 1993). The process has been used to treat about 1,350 tons (1,225 metric tons) of lead-bearing materials from the NL Industries Superfund site.

Table 3-6. United States Secondary Lead Smelters (November 1993) (Source: Smith et al., 1995)

Smelter Location	Year Built	Approximate Capacity MTPY[a]	Furnace Type[b]
Ponchatoula, LA	1987	8,000	BF-SRF
Boss, MO	1991	65,000	REV (Paste) SRF (Metal)
Lyon Station, PA	1964	54,000	REV-BF
Muncie, IN	1989	70,000	REV-BF
Reading, PA	1972	65,000	REV-BF
College Grove, TN	1953	10,000	BF
Eagan, MN	1948	55,000	REV-BF
Tampa, FL	1952	18,000	BF
Columbus, GA	1964	22,000	BF
Frisco, TX	1978	55,000	REV-BF
Los Angeles, CA	1981	90,000	REV-BF
Rossville, TN	1979	9,000	BF
City of Industry, CA	1950	110,000	REV
Indianapolis, IN	1972	110,000	REV-BF
Wallkill, NY	1972	70,000	REV
Troy, AL	1969	110,000	REV
Baton Rouge, LA	1960	70,000	REV-BF
Forest City, MO	1978	27,000	BF
Total secondary lead smelting capacity		1,023,000	

(a) As lead metal.

(b) BF = blast furnace; REV = reverberatory furnace; SRF = short rotary kiln.

4.0 EVALUATING RECYCLING OPTIONS FOR SPENT ABRASIVE

This section describes factors to consider when evaluating reuse and recycling options for spent ABM and other similar wastes.

4.1 Contaminant Characteristics

The types of contaminant present, their concentration, and their physical and chemical forms are major considerations in selection of a reuse or recycling option. Questions should be asked about the critical features of waste composition:

- Is the spent ABM suitable for cleaning and reuse?
- Will a mixture of metals in the waste complicate recycling?
- Will inorganic salts in the waste complicate recycling?
- Will organics in the waste complicate recycling?

The contaminant composition is determined by chemical and mineralogical analysis on a representative group of samples. The analysis should go beyond determining the concentration of the contaminants. The chemical form and speciation are important factors when considering recycling options. Matrix properties also are important (see Section 4.2).

Some fraction of the spent ABM will have the required particle size and shape to allow reuse for blasting if the impurities can be removed. Physical separation, thermal processing, or a combination of the two methods may be used to recover and restore the usable portion of the spent material.

A waste containing a limited number of contaminants generally is easier to recycle. Wastes containing a single type of metal contaminant are more likely to be suitable for higher-value uses. Segregating hazardous from nonhazardous wastes can be particularly helpful. Finding recycling options will be more difficult if the waste has a RCRA hazardous waste designation. It is often beneficial to separate spent ABM to be used for cleaning newer ships from spent ABM to be used for cleaning older ships. In 1977, the Consumer Product Safety Commission banned the use of lead-containing paints for residential use. Although there is no specific regulation banning the use of lead-containing paints for industrial coatings, lead primers have been nearly eliminated from use since the early 1980s (Leighton, 1995). Older coating materials containing lead can cause the spent ABM to be a RCRA-listed hazardous waste. If all spent ABM wastes were mixed, the volume of hazardous waste could be increased and recycling options decreased. However, plans for waste segregation should consider the desire of end users for a reliable supply of homogeneous material and the added cost of sampling and analyzing many different waste groupings (see Section 4.4.2).

Antifouling additives are a unique feature of marine coatings. The compounds used in antifouling paints for ships can introduce metal contaminants to the spent ABM. These antifouling paints serve a pest control function and must, therefore, be registered under the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA). Copper-based antifouling coatings traditionally were favored but were largely replaced by organotin formulations that gave more reliable protection. Use of organotin antifouling coatings has been restricted worldwide, and the FIFRA registration of organotin coatings is under review by the U.S. EPA. With the increased regulatory scrutiny, the popularity of organotin antifouling coatings has been declining (Holder and Montemarano, 1995).

Inorganic salts can interfere with specific recycling options. For example, chlorides increase the volume of kiln dust waste from cement manufacturing and chlorides or sulfates produce acidic off-gas from thermal processes.

The presence of high concentrations of organic contaminants can complicate the recycling of spent ABM, but petroleum contaminants can be acceptable with some recycling options. Organic contaminants with properties similar to bitumen (e.g., the higher-molecular-weight hydrocarbons) are compatible with asphalt. Therefore, petroleum hydrocarbons may be tolerated, if the spent ABM is to be used for asphalt. Vitrification and cement-making require energy input; therefore, the waste can contain an organic contaminant if it burns to provide energy and does not add impurities or produce unacceptable off-gas.

4.2 Waste Characteristics

The waste matrix properties will affect the acceptability of the waste material for various recycling methods. For construction applications, the material matrix is the recycled product. The waste matrix affects the compatibility of the waste matrix with the intended end use. Review of waste matrix effects is aimed at answering these types of questions:

- Is the waste matrix compatible with the existing recycling processing techniques and equipment?

- Will the waste matrix increase or decrease contaminant mobility?

- Does the matrix have value as a bulk commodity?

The potential user of a recyclable waste will prefer a material with physical and chemical properties similar to those of the conventional raw material. In general, there will be a preference for a dry granular solid with a uniform concentration. The highest possible and most permanent leaching resistance is desirable and, of course, all regulatory leaching resistance requirements must be met.

Any recycling option will require simple pretreatment of the waste to upgrade, blend, or otherwise develop more uniform or desirable characteristics for the end user. At a minimum, the waste should be passed through a large mesh screen to remove trash and oversize material. Additional physical separations processing may also be useful. For example, crushing to reduce the size of large clumps followed by screening to remove both oversize debris and undersize dust will produce a more uniform particle-size material and may increase the value or range of applicable recycling options.

More complex separation processes are available to upgrade the spent ABM. Magnetic separation can remove ferromagnetic metals. Beneficiation processes involving water-assisted physical separation such as jigging, hydrocyclone separation, or tabling separate particles based on size, shape, and density. However, the added cost of the more complex beneficiation methods is more difficult to justify when dealing with wastes that are suitable only for lower-value uses.

It is important to note that conventional materials are not totally free of trace metal impurities. The metal content of the spent ABM may be within the range of composition of the conventional material it replaces. The trace element content of soils is shown in Table 4-1 to provide a general basis for comparison.

4.3 Site Characteristics

Site characteristics such as infrastructure capabilities and support service supplies may either favor or interfere with removal or handling of the waste material. Examination of site characteristics is directed at answering these types of questions:

Table 4-1. Trace Element Content of Soils

Element	Common Range in Soil (mg/kg)	Average Concentration in Soil (mg/kg)
Ag	0.01 to 5	0.05
As	1 to 50	5
B	2 to 100	10
Ba	100 to 3,000	430
Be	0.1 to 40	6
Cd	0.01 to 0.7	0.06
Co	1 to 40	8
Cr	1 to 1,000	100
Cs	0.3 to 25	6
Cu	2 to 100	30
Ga	0.4 to 300	30
Hg	0.01 to 0.3	0.03
Mg	600 to 6,000	5,000
Mn	20 to 3,000	600
Mo	0.2 to 5	2
Ni	5 to 500	40
Pb	2 to 200	10
Sb	2 to 10	No data
Se	0.1 to 2	0.3
Sn	2 to 200	10
Sr	50 to 1,000	200
U	0.9 to 9	1
Y	25 to 250	50
Zn	10 to 300	50

Source: U.S. Environmental Protection Agency, 1983, SW-874.

- Is the material accessible for removal?
- Can the contaminated solid be moved efficiently by conventional bulk material handling equipment and techniques?
- Will the on-site and off-site infrastructure support transport of the waste materials?
- Are the required utility supplies and support services available?

Removal logistics are determined by access to the contaminated site for excavation, the ability to handle excavated material, space for placement of aboveground treatment equipment, and the road and rail system on and around the site. Recycling usually requires development of storage areas to allow for pretreatment of the waste (see Section 4.2), to accumulate sufficient volumes of uniform feed to satisfy user needs, and to stockpile material between projects. The surge storage will increase space requirements and may increase regulatory concerns.

Data needed to evaluate the removal logistics include maps of the site and surroundings. Important features to consider include the general arrangement of structures and infrastructure and the location of critical environments or sensitive receptors.

4.4 Economic Factors

Economic factors including costs, market conditions, and time available for remediation play a major role in the identification and selection of recycling options.

4.4.1 Operating and Capital Costs

A reuse or recycling option is evaluated as a competitor among a group of options. To be acceptable, an option must effectively protect human health and the environment. In most cases, once effective options are identified, the one with the lowest implementation cost is selected. The economic analysis will need to consider the capital investment required to implement the candidate options and the overall cost of the recycling versus treatment and disposal. Questions typically considered as part of the economic evaluation include:

- Is there a profitable recycling option?
- Will consideration of life-cycle cost factors improve the competitive position of recycling?
- Do intangible factors favor recycling?
- Does recycling require a major investment of capital?

The value or cost of recycling spent ABM will be determined by competition with other raw materials in the marketplace. If a paying recycling market is identified for the spent ABM, treatment and disposal options should not be considered.

There usually will be a fee associated with recycling options for spent ABM and similar wastes. Recycling options will then need to be evaluated in competition with treatment and disposal alternatives, except where treatment and disposal are precluded by land ban requirements (e.g., wastes containing high concentrations of mercury or emission control dust or sludge from electric arc furnaces K061).

The economic analysis should include both direct costs and avoided expenses through the life cycle of the alternative considered. Intangible factors such as improved public image or the potential for liability should be considered. It may be appropriate to include some correction for costs that may occur but that cannot be quantified. For example, disposal options may result in liability for cleanup at a future date.

The relative capital costs can also influence a decision. Even if one option has a lower life-cycle cost, a higher total cost option with lower capital cost may be chosen due to limited availability of capital.

4.4.2 Recycling Market

The recycled spent ABM must compete effectively with conventional products filling the same needs. The competitive position of the contaminated material should be considered to address questions such as these:

- Will the recycled product equal or exceed the performance of competing products already in the market?

- Are adequate markets available within a reasonable shipping distance?

- Will the volume of material available for recycle justify the effort required to do the recycling?

Products formed from waste materials must meet or exceed the performance specifications of existing products. For example, ASTM C 825, "Specification for Precast Concrete Barrier," describes the required characteristics of formed concrete products given in the specification for New Jersey barriers.

The barrier specification combines requirements on materials, design, manufacture, and physical performance. The materials used (cement, aggregates, air-entrainment additives, and steel reinforcement) must meet applicable ASTM specifications. The design factors specified are concrete strength and air content, dimensions, reinforcement placement, finish, lifting devices, and anchorage points. Requirements for the manufacturing steps of mixing, curing, and forming are given. Test methods and required performance are given for compressive strength and dimensional tolerance.

The form of the barrier specification illustrates one hurdle for waste-derived products. For many waste-derived products, the materials and method of manufacture are totally different from those used in making the existing product. The customer may be unwilling to accept the new manufacturing methods even when the measured physical and chemical properties are equal or superior. The customer is concerned that the quality of the product is affected in part by features or interactions too complex to be measured by physical properties alone, so the quality of the raw materials and the production process must be specified and controlled. As a result, a waste-derived product often must undergo a lengthy demonstration to prove performance in real-world applications.

The location of the site and the volume of spent ABM can influence the economic viability of recycling. The shipping, handling, and storage costs can be a significant portion of the total cost, particularly with low-unit-value aggregate or construction materials. A waste source located near the end user will reduce shipping costs.

Industrial users prefer a steady supply of consistent materials. The desire for a homogeneous feedstock often is not consistent with the realities of waste production. Both the matrix composition and the contaminant levels in wastestreams can be highly variable. Also, as discussed in Section 4.1, waste segregation can help reduce the volume of hazardous wastes produced but will increase the number of waste types. Waste segregation efforts must consider a tradeoff between reducing the volume of hazardous wastes versus the increased complexity introduced by having many waste types. When wastes are segregated in small batches, each batch must be characterized, increasing sampling and analysis costs and increasing the challenges in marketing several smaller volumes of wastes.

Preprocessing the waste to improve homogeneity is a possible approach to improving market acceptance. However, additional processing increases the cost to implement the option and the complexity of the equipment needed on site.

4.4.3 Time Available for Remediation

Evaluation of reuse and recycling options should consider the amount of time required to mobilize, operate, and demobilize the selected option in relation to the time actually available to perform the work. Consideration of the timing of the options is directed at answering these types of questions:

- Can the cleanup be completed in a time frame consistent with health, safety, and environmental protection?

- Can the cleanup be completed in a time frame consistent with the end use requirements?

The time available for remediation is controlled primarily by the need to protect human safety and health and the environment. If a toxic contaminant is present, the contaminant concentration is high, or the contaminant is mobile and near a critical ecosystem, the remediation must proceed quickly. Time available may be controlled by the value or intended end use for the site. It is undesirable to keep a high-value site out of productive use for a long period.

Identification of recycling options, definition of applicable specifications, testing to determine their suitability, and negotiating contracts to do the recycling can require more time than conventional treatment technology. If the contaminant presents an imminent danger due to hazard level, mobility, or other factors, rapid remediation is needed. The need for rapid remediation of an imminent hazard favors treatment.

The importance of the length of remediation time may be lessened if the time constraint is driven by economic or end use requirements. Depending on the site logistics and the site use, it may be possible to continue routine site operations while material is removed (and, if appropriate, while it is processed on site) for recycling. However, the need for rapid remediation still generally increases the favorability of treatment technologies.

4.5 Regulatory Considerations

Regulatory constraints describe the overall regulatory climate at the site based on federal, state, and local regulations. Typically the recycled material fills only a small portion of the user's feed material requirements. Should the regulatory requirements or liability concerns be large, the user typically has a competitive source of virgin material to replace the recycled material. As a result, regulatory issues can present a significant challenge to recycling of materials with a RCRA waste code or coming from a Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) site. Examination of regulatory standards is directed at answering such questions as these:

- What contaminant control levels are required?
- Are the materials controlled by RCRA hazardous characteristics or listings?
- Are the materials controlled by state or local hazardous or industrial waste regulations?
- Can a valid reuse, reclamation, or recycling process be applied to exempt RCRA waste?

Regulatory considerations often are the most important factors influencing the viability of a particular recycling option. Therefore, before plans for recycling are pursued in depth, it is important to determine the federal, state, and local regulations that may be applied to a particular site, waste material, and/or recycling option.

Regulations pertaining to recycling vary widely from state to state; in addition, the prevailing attitude on the part of the regulator towards recycling will vary based on a number of factors, such as prior track record, perceived risk, and other factors. It is not possible here to define or predict the compliance issues that may be encountered on a project-by-project basis. The remainder of this section summarizes U.S. EPA and some examples of state regulations that pertain to the recycling of spent ABM. The discussion of state regulations and policy pertains primarily to California, Oregon, and Washington but may provide some generic perspective on the types of compliance issues that may be encountered in other states as well.

4.5.1 Federal Regulations — RCRA

One of the first steps in identifying the regulatory requirements is to determine if the spent ABM is considered a hazardous waste under RCRA. This law and the regulations issued pursuant to the law place stringent requirements on the storage, treatment, and disposal of hazardous waste. Under RCRA, a waste may be considered hazardous if it is either specifically listed (e.g., certain spent solvents from certain processes or specific chemicals) or it may be hazardous by characteristic (i.e., it is ignitable, reactive, corrosive, or "toxic" based on the TCLP). For spent ABM, it is most often the metals from the paints (e.g., lead) that cause the waste to fail the TCLP and thus be considered a RCRA hazardous waste.

Because of extensive regulatory tracking, reporting, testing, and in some cases, permitting requirements, and because of concerns for future liability, many companies are not willing to accept RCRA hazardous wastes as substitutes for their normal raw materials. Therefore, it is important to know if the waste is RCRA hazardous and to discuss any proposed reuse/recycling with the potential recycler before proceeding. In addition, the U.S. EPA or their delegated regulatory agency has authority over recycling of RCRA hazardous wastes and it is critical to determine whether the recycling option will be allowed by the regulatory agency before engaging in the process.

The regulation of recycling RCRA hazardous waste is a complex and evolving area. The U.S. EPA is considering revising the existing regulations to make legitimate recycling easier; however, these revisions are not yet in place. The regulation of recycling is still quite complex and is often determined on a case-by-case basis. An overview of the existing recycling regulations and policies is discussed below.

Rules issued by U.S. EPA on January 4, 1985 (50 FR 614) acknowledged the need to encourage safe recycling of hazardous wastes — particularly when recycling clearly reduces potential harm — while at the same time assuring the abatement of pollution and the prevention of harm to human health and the environment.

For a secondary material to be regulated under RCRA Subtitle C, a substance must first meet the definition of a "solid waste." Section 1004(27) of RCRA defines solid waste as:

> any garbage, refuse, sludge, ... and other discarded material, including solid, liquid, semisolid, or contained gaseous material resulting from industrial, commercial, mining, and agricultural operations and from community activities.

A central element of this definition is that wastes are "discarded." In 1985, the U.S. EPA revised the definition of solid waste to further clarify when a secondary material that will be recycled is considered a solid waste. Under the regulatory definition of solid waste, found in 40 CFR 261.2(a-f), a secondary material is defined as a solid waste if:

- it is abandoned
- it is recycled in certain ways, or
- it has been defined as "inherently waste like."

The term "secondary material" refers to spent materials, sludges, byproducts, commercial chemical products, and scrap metals. "Spent material" is defined as a material that has been used, which as a result of contamination can no longer serve the purpose for which it was produced without further processing. When any of the five types of secondary materials are "recycled in certain ways," they may or may not be defined as solid wastes. The U.S. EPA has made distinctions between recycling that is regulated as waste management and recycling that is exempt from regulation, depending on the type of secondary material and the manner in which it is being managed.

With respect to the second item, "recycled in certain ways," secondary materials are solid wastes, and thus are subject to regulation, when they are recycled in the following four ways:

- used in a manner constituting disposal (i.e., applied to the land or used to produce a product that is placed on the land) [note that use of hazardous waste in asphalt and concrete generally is considered use constituting disposal.]

- burned for energy recovery (including use to produce a fuel)

- reclaimed (processed to recover a usable product or component or regenerated), or

- accumulated speculatively (material stored with less than 75% recycled within 1 calendar year).

The regulations state that when any of the secondary materials identified above is recycled in any of the four ways indicated, it is defined as a solid waste, with four primary exceptions:

- characteristic sludges being reclaimed
- characteristic byproducts being reclaimed
- commercial chemical products being reclaimed, or
- commercial chemical products being speculatively accumulated.

Characteristic sludges and byproducts used in any of the remaining three ways (i.e., placed on the land, burned for energy recovery, or accumulated too long before recycling) are solid wastes. Commercial chemical products that are placed on the land or burned for energy recovery also are solid wastes, unless that is their ordinary use.

In addition to the exclusions discussed above, the U.S. EPA recognized other situations that closely resemble production processes and, therefore, are excluded from regulation under the RCRA program. Materials are not solid wastes when they are legitimately recycled by being:

- used or reused as an ingredient in an industrial process to make a product, provided the materials are not first reclaimed

- used or reused as effective substitutes for commercial products provided they have not been reclaimed, or

- returned to the original process from which they were generated without first being reclaimed (material must be used as a substitute for raw material feedstock).

These materials are not considered solid waste.

Although the direct reuse provisions exempt certain materials from being solid wastes, there are limits to these exemptions. Materials that are used/reused as ingredients or substitutes for commercial products, but are also placed on the ground or incorporated into products placed on the ground (i.e., that are used in a manner constituting disposal) remain solid wastes. Also, if a material is used or reused by being burned for energy recovery or used to produce a fuel, it remains a solid waste. Finally, if a material is speculatively accumulated or is "inherently waste like," the material remains a solid waste regardless of the manner in which it is recycled.

The burden of proof that a particular material is not a solid waste and is, therefore, exempt from regulation lies with the person making the claim. This person must be able to demonstrate that there is a market for the material and that the specific use/reuse meets the condition of the exclusion. Closed-loop recycling processes also are excluded from regulation (40 CFR 261.4).

In addition, three case-by-case variances can be granted by the Regional EPA Administrator to exclude a material from classification as a "solid waste," the following two of which involve recycling:

- A material is reclaimed and then reused as a feedstock within the original primary production process in which the material was generated if the reclamation operation is an essential part of the production process, or

- A material has been reclaimed but must be reclaimed further before recovery is complete if, after initial reclamation, the resulting material is commodity-like.

The U.S. EPA has also established a policy identifying criteria that may indicate sham recycling that is actually a surrogate for hazardous waste treatment or disposal. If a person uses a secondary material as is (in a production process), that person must be able to show that the secondary material is as effective as the raw material it is replacing. Also, if the material does not contribute any necessary or significant element to a product of the production process, the recycling may be a sham. Other indicators of sham recycling are use of a secondary material in excess of the amount necessary for a particular process and the handling of a secondary material without regard to economic loss. The burden of proof for the legitimacy of a claimed regulatory exemption rests solely on the recycler.

For secondary materials subject to regulation as a solid waste and potentially as a hazardous waste, specific standards exist for some types of hazardous waste reuse or reclamation activities. Generators and transporters of recyclable materials (hazardous wastes that will be recycled) generally are subject to 40 CFR Parts 262 (generator requirements) and 263 (transporter requirements) of Subtitle C, as well as notification requirements of Section 3010 of RCRA. Additionally, recycling facilities that store recyclable materials prior to recycling are subject to notification requirements and Subtitle C hazardous waste storage requirements. However, in general, the recycling process itself currently is exempt from regulation under Subtitle C. Recycling facilities that do not store recyclable materials before recycling are subject only to Subtitle C notification and manifest requirements.

Some particular recyclable materials are not subject to the full generator, transport, and storage requirements of Subtitle C, but are only subject to the limited provisions of Part 266 (again, the actual recycling process is not regulated; only the storage prior to recycling is subject to full Subtitle C regulation). Recyclable materials regulated under Part 266 include:

- hazardous waste burned for energy recovery
- precious metal reclamation
- spent lead-acid batteries
- recyclable materials used in a manner constituting disposal.

4.5.2 State and Local Regulations

State and local requirements can vary widely. Therefore, it is important to determine what the requirements are for a specific location. For spent ABM that is not RCRA hazardous, the following regulatory agencies potentially could have cognizance:

- state air board or air quality management district
- state water board
- state environmental protection agency (or department of environmental protection)
- county department of public health (or similar agency, if applicable)
- city department of public health (or similar agency, if applicable).

The names of these organizations may vary widely from region to region, and the above list is not necessarily complete. A list of addresses and phone numbers of state environmental regulatory agencies, and a list of U.S. EPA information hotlines and other sources of regulatory information pertaining to recycling are provided in Appendix B.

Some states have established requirements that are more stringent than those of the federal government for determining what waste is considered hazardous. Thus, spent ABM that is not hazardous under RCRA potentially could be considered hazardous by a particular state and must be handled and disposed of according to the state or local requirements. For example, California requires a slightly different testing procedures for determining toxic metals content and leachability. Also, the state has established lower concentrations for toxic metals and includes several additional metals such as copper that are not regulated under RCRA.

4.5.2.1 Summary of California EPA Policy Regarding "Use in a Manner Constituting Disposal." California is one of a handful of states that have promulgated policy pertaining to recycling hazardous wastes into construction materials and specifying acceptance criteria for the types of wastes or byproducts that may be recycled. On August 18, 1995, the California EPA, Department of Toxic Substances Control (DTSC), Alternative Technology Division in Sacramento issued a management memo dated August 1995 for "The Use of Recyclable Materials in Asphalt Concrete and Concrete (Use Constituting Disposal or UCD)" (Appendix C). The purpose of this policy is to encourage the recycling of suitable wastes into construction materials and to establish conditions to assure that the recycling occurs safely and can be monitored as necessary to prevent abuses. Several of these conditions, which are described more fully in Appendix C, are as follows:

- The policy applies only to non-RCRA (California-only) hazardous wastes.

- For wastes failing the California WET test, the contaminant in the resulting construction material needs to be "chemically-bound." The effect of contaminant dilution by other ingredients in the construction materials needs to be accounted for by increasing the measured leachable concentration by the dilution factor so that the component of immobilization due to chemical binding can be assessed. The WET soluble metal content of the asphalt-treated ABM must adhere to STLC standards after accounting for the effect of dilution.

- Recyclable materials should add no significant hazard to public health or the environment, either in the recycling process or in the final product.

- The recyclable materials must be used beneficially; that is, the material must meet accepted performance standards such as Caltrans (California Department of Transportation) specifications and must be made for commercial use.

Clearly, compliance with these criteria will involve some testing and evaluation. Demonstrating compliance with the metals leaching criteria will require laboratory or field treatability tests to evaluate the extent of metals immobilization due to asphaltic binder ingredients. Compliance with the criteria pertaining to hazards posed by the recycling process or product may require the performance of a quantitative risk assessment.

4.5.2.2 California Hazardous Waste Management Compliance Issues. The regulations summarized above specify when a hazardous byproduct is recyclable. Once that recyclability is demonstrated, for category 2 and 3 wastes, it will still be necessary to manage that recycling project in compliance with applicable state, local, and/or U.S. EPA waste management regulations.

As in the previous sections, it is not possible to define these regulations and policies for every region, as they will vary significantly from region to region. However, it is instructive to indicate the types of compliance issues that may exist, using California as an example.

In California, hazardous waste control requirements are set forth in the California Health and Safety Code, Division 20, Chapter 6.5, Section 25100 et seq. and regulations have been adopted to implement this section of the statutory code. Recyclable materials are subject to these requirements unless a variance is issued by the California DTSC or unless the material is excluded or exempted from classification as a waste under Section 25143.2(b), (c), or (d) or California's hazardous waste management regulations (adopted pursuant to Sections 25150 and 25151).

Materials exempted or excluded under Section 25143.2, subdivisions (b) or (d), must be managed in accordance with the requirements for management of a recyclable material specified in 25143.9. Under 25143.9(a), if a material is held in a container or tank, the container or tank must be labeled, marked, and placarded in accordance with DTSC hazardous waste labeling, marking, and placarding requirements applicable to generators, except that the container or tank would be labeled or marked clearly with the words "Excluded Recyclable Material" instead of the words "Hazardous Waste," and manifest document numbers would not be applicable.

Under 25143.9(b), the owner or operator of the business location where the material is located must have a business plan that meets the California requirements given in Section 25504, including but not limited to, emergency response plans and procedures, as described in subdivision (b) of Section 25504, which specifically address the material meet the DTSC's emergency response and contingency requirements that are applicable to generators of hazardous waste.

Section 25143.9(c) requires that the recyclable material be stored and handled in accordance with all local ordinances and codes governing the storage and handling of the hazardous material, including but not limited to, fire codes. If a local jurisdiction does not have an ordinance or code requiring secondary containment for hazardous material storage areas, then the material must be stored in tanks, waste piles, or containers meeting the DTSC's interim status regulations establishing design standards applicable to tanks, waste piles, or containers storing hazardous waste. Finally, under Section 25143.9(d), there are additional requirements if the material is being exported to a foreign country.

Although recyclable materials are not required to comply with the same regulations applied to hazardous waste generators, there is a statutory provision that affects the length of time that recyclable materials can be stored. Under Section 25413.2(e), materials that are accumulated speculatively do not qualify for the exemptions under Section 25143.2. Because California has not specified a definition of speculative accumulation, the definition established by the U.S. EPA in 40 CFR 261.1(c)(8) applies. Under this definition, a recyclable material is not accumulated speculatively if the person accumulating it can show that the material is potentially recyclable and has a feasible means of being recycled; and that during the calendar year (commencing on January 1), the amount of material that is recycled or transferred to a different site for recycling equals at least 75% by weight or volume of the amount of that material accumulated at the beginning of the period.

Persons recycling more than 100 kilograms per month of recyclable material are required to provide reports to the local health officer or other local public officer authorized to implement the statute (see Section 25143.10). The following information is required to be provided in writing every 2 years:

- the name, site address, mailing address, and telephone number of the owner or operator of any facility that recycles the material
- the name and address of the generator of the recyclable material
- documentation that the requirements of any exemptions or exclusions pursuant to Section 25143.2 are met including, but not limited to, all of the following:
  - where a person who recycles the material is not the same person who generated the recyclable material, documentation that there is a known market for disposition of the recyclable material and any products manufactured from the recyclable material.
  - where the basis for the exclusion is that the recyclable material is used or reused to make a product or as a safe and effective substitute for a commercial product, a general description of the material and products, identification of the constituents or group of constituents, and their approximate concentrations, which would render the material or product hazardous under the regulation adopted pursuant to Sections 25140 and 25141, if it were a waste, and the means by which the material is beneficially used.

This information must be provided in the format developed by the California Conference of Directors of Environmental Health in consultation with the DTSC. Also, if the person recycling the material is not the same person who generated the recyclable material, then the person who recycles the material is required to provide the generator with a copy of the information listed above.

If the exclusion of the recyclable material is questioned and the regulatory authority brings action against owner or operator using the recyclable material, the burden of proof that the exclusion is valid lies with the owner or operator, not with the agency. The owner or operator would be required to provide information on the management of the material and to maintain adequate records to demonstrate that there is a market for disposition of the material (Section 25143.2, subdivision (f)).

4.5.2.3 Spent ABM Reuse in Washington and Oregon. The states of Washington and Oregon each have state regulations that potentially could favor recycling of state-only hazardous waste because of restrictions on landfilling such materials. A brief summary of these regulations is discussed below.

Washington's Dangerous Waste Guidelines (Washington Administrative Code [WAC] Chapter 173-303) have adopted TCLP testing parameters that are identical to the federal regulations specified under RCRA. However, Washington Department of Ecology Technical Information Memorandum (TIM)

86-1 specifies additional analytical testing requirements for foundry slag and baghouse wastes from the sandblasting industry. TIM 86-1 specifies three additional metals: copper, nickel, and zinc. This memorandum stipulates that if the cumulative concentrations of these three metals in their soluble form exceeds 5 parts per million (ppm), then additional criteria under aquatic toxicity testing must be reviewed prior to disposal through a municipal facility. These criteria may not apply if the materials are recycled or used in additional industrial processes. It is not clear how this would apply to spent ABM; however, recycling potentially could be more favorable if the presence of these metals caused disposal costs to be greater.

The Oregon Hazardous Waste Guidelines (Oregon Administrative Rules (OAR) Chapter 340) also have adopted the federal TCLP criteria for heavy metals. However, the Oregon Department of Environmental Quality has recently promulgated legislation for the management of ABM from ship repair activities. This segment of legislation specifically targets the ship repair industry and the use of antifouling paints. Under this regulation, spent antifouling residues may be considered pesticides. Because antifouling paints are potential pesticides, and sandblast grit waste containing such is subject to Oregon's Aquatic Toxicity Test (OAR 340-101-033). If the sandblast grit fails the original TCLP parameters, the material is then classified as a federally regulated hazardous waste and an aquatic toxicity test is not necessary; it must be managed as a hazardous waste. If the waste passes the TCLP test and fails the aquatic toxicity test, it is classified as an Oregon State-Only dangerous waste and must be managed as a hazardous waste. Upon further review of this legislation, this rule is applicable to materials primarily managed and disposed through municipal landfill facilities and does not include those wastes managed through a legitimate recycling or reuse program. The Department of Environmental Quality does allow disposal of spent grit that fails the aquatic toxicity test if the solid waste landfill meets design criteria specified in 40 CFR 258.40.

5.0 SUMMARY AND CONCLUSIONS

Section 2 describes physical and chemical aspects of new and spent ABM, Section 3 discusses some specific approaches to recycling spent ABM, and Section 4 describes factors to consider when reviewing and selecting recycling options. These sections outline some guideposts to possible markets for your spent ABM or similar wastes and indicate factors to consider when searching for recycling options. The analysis is a complex task which must be done for a specific waste material.

Due to the lack of a clear definition of what constitutes valid recycling, the user needs to be particularly careful when identifying options for hazardous material recycling. The ultimate interpretation rests with the federal and local regulators.

Once the potential markets are identified, some basis must be found for establishing specifications for materials. Reliable materials commerce requires some acceptable standards describing the composition, quality, and properties of recycled materials. The specifications may be based on the material origin, composition, end use performance, or other characteristics. Potential end users may avoid recycled material if they are uncertain about the impurity levels or how well the quality of the material will be controlled.

In general, developing a specification will require negotiation between the supplier and user. Some guidance is available in the form of ASTM or other specifications that include or can be applied to recycled materials. The U.S. EPA, under the provisions of RCRA, is encouraging government agencies to allow use of recycled materials. However, most existing specifications are written to ignore or possibly even preclude recycled materials. Creative use of existing specification may be needed to reach a definition of material composition and properties that is acceptable to the buyer and seller.

Material characterization for recycling requires a somewhat different outlook and approach than is typical for waste treatment studies. Waste characterization for waste treatment and disposal usually focuses mainly on the amounts of contaminant present. The mineral form of the contaminant and the composition and form of the matrix are considered only in light of how they may affect the performance of treatment or disposal options. Recycling requires thinking of the entire body of waste material as a product. As a result, its total composition, chemical speciation, and physical form need to be established early in the characterization process.

Waste materials, particularly those from CERCLA sites, usually have highly variable compositions. End users prefer a reliable stream of materials with predictable composition. The waste supplier may, therefore, need to provide pretreatment to homogenize and sample the material to prepare a product that is acceptable for the user.

In the face of competition for traditional raw materials sources, the waste generator or supplier often needs to take an active role to seek out uses for the waste material. Recycling can succeed only if there are markets for the waste material. In general, users of recycled materials are in a buyer's market. A large new source of waste materials available for recycling can saturate end use markets. These elements can help in finding a home for waste materials:

- established and effective specifications
- creative efforts to identify possible uses

- providing a reliable supply of consistent material
- programs to improve public awareness of recycling potential.

These seem daunting tasks that lie beyond the scope of normal waste processing and disposal. However, significant benefits can be achieved in reduced liability and possibly reduced cost if the waste material is recycled rather than sent for disposal.

The individual waste generator can contribute, but efforts are needed from a variety of groups to help expand recycling of industrial wastes. The task is not impossible. Europe has installed an infrastructure for recycling a variety of industrial wastes. Technologies and systems are growing in the United States to support recycling.

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APPENDIX A

ABRASIVE BLASTING MEDIA QUALIFIED FOR USE ON U.S. NAVY SHIPS

QUALIFICATIONS CERTIFIED
MAY 1990

QPL-22262-18
20 June 1995
SUPERSEDING
QPL-22262-17
21 May 1993

QUALIFIED PRODUCTS LIST

OF

FSC 5350

PRODUCTS QUALIFIED UNDER MILITARY SPECIFICATION

MIL-A-22262

ABRASIVE BLASTING MEDIA
SHIP HULL BLAST CLEANING

This list has been prepared for use by or for the Government in the acquisition of products covered by the subject specification and such listing of a product is not intended to and does not connote indorsement of the product by the Department of Defense. All products listed herein have been qualified under the requirements for the product as specified in the latest effective issue of the applicable specification. This list is subject to change without notice; revision or amendment of this list will be issued as necessary. The listing of a product does not release the contractor from compliance with the specification requirements.

THE ACTIVITY RESPONSIBLE FOR THIS QUALIFIED PRODUCTS LIST IS THE NAVAL SEA SYSTEMS COMMAND, SEA 03R42, 2531 JEFFERSON DAVIS HWY, ARLINGTON, VA 22242-5160.

GOVERNMENT DESIGNATION	MANUFACTURER'S DESIGNATION	TEST OR QUALIFICATION REFERENCE	MANUFACTURER'S NAME AND ADDRESS
	BARTON 1640 GARNET	NAVSHIPYD, MARE 9631, Ser 134.6/62 and NEHC Rpt. 6266, Ser 34Bdbm 06015	Barton Mines Corp. P.O. Box 400 North Creek, NY 12853 Plant: Hudson River Plant Route 28 North Creek, NY 12853
	STARBLAST XL	NAVSHIPYD, MARE 9631, Ser 134.6/79 and NEHC Rpt. 6260, Ser 34Bnhp/2014	E.I. du Pont de Nemours & Co., Inc. Chestnut Run Plaza Building 709 Wilmington, DE 19880-0709 Plant: Florida Plant Route 230 Starke, FL 32091

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GOVERNMENT DESIGNATION	MANUFACTURER'S DESIGNATION	TEST OR QUALIFICATION REFERENCE	MANUFACTURER'S NAME AND ADDRESS
	Emerald Creek Garnet	NAVSHIPYD, MARE 9631, Ser 134.6/ 158 and NEHC Rpt. 6270, Ser 342/0548	Emerald Creek Garnet P.O. Box 190 Fernwood, ID 83830 Plant: Route 4 Emerald Creek Road Fernwood, ID 83830
	Black Diamond	NAVSHIPYD, MARE 9631, Ser 134.6/ 151 and NEHC Rpt. 4121, Ser 34Bvs/ 02176	Foster Dixiana Corp. P.O. Box 2005 Columbia, SC 29202 Plant: 5360 Bainbridge Blvd. Chesapeake, VA 23320
	Black Diamond (CX-8)	NAVSHIPYD, MARE 9631, Ser 134.6/ 56 and NEHC Rpt 4123, Ser 34Dndb/ 01007	Foster Dixiana Corp. P.O. Box 2005 Columbia, SC 29202 Plant: Hardeeville Ind. Park - Hwy. 321 Hardeeville, SC 29927
	ROM 30x60 Garnet Abrasive GMA 30X60 GMA 60 mesh GMA 80 mesh	NAVSHIPYD, MARE 9631, Ser 134.6/ 178 and NEHC Rpt. 6270, Ser 34Bns 06336	Garnet Millers Assoc. Pty. Ltd. (GMA), c/o Barton Mines Corp., Suite 190 1658 Cole Blvd. Golden, CO 80401 Plant: Gould Road Geraldton, WA 6530 Australia
	CAMEL BLACK	NAVSHIPYD, MARE 9631, Ser 134.6/95 and NECH Rpt. 6270 Ser 34B/4697	Genstar Stone Products Company Executive Plaza IV Hunt Valley, MD 21031-1091 Plant: 10300 Pulaski Highway White Marsh, MD 21162

GOVERNMENT DESIGNATION	MANUFACTURER'S DESIGNATION	TEST OR QUALIFICATION REFERENCE	MANUFACTURER'S NAME AND ADDRESS
	GREEN DIAMOND	NAVSHIPYD, MARE 9631, Ser 134.6/61 and NEHC Rpt. 6270, Ser 34Baj/06016	Glenbrook Nickel Co. 5094 Glenbrook Loop Rd P.O. Box 85 Riddle, OR 97469 Plant: 6th & E Street Riddle, OR 97469
	Kleen Blast	NAVSHIPYD, MARE ISLAND Rpt. 9631 Ser 134.6/34 & NEHC Rpt. 6270 Ser 42p/08213	Kleen Blast Abrasives 2400 Old Crow Canyon Road, #AZ San Ramon, CA 94583 Plant: Pacific Abrasive and Supply West Carson Rd. Grand Forks, B.C. Canada VOH 1-HO
	Sharpshot M-60 Sharpshot F-80	NAVSHIPYD, MARE ISLAND Rpt. 9631 Ser 134.6/67 & NEHC Rpt. 6266 Ser 422mb/12025	Minerals Research & Recovery of Arizona, Inc. 4565 South Palo Verde Suite #203 Tucson, AZ 85714 Plant: Highway 85 Ajo, AZ 85321
	Ferro-Blast/ Best Grit 73	NAVSHIPYD, MARE Rpts. 9631, Ser 134.6/25 & 9631, Ser 134.6/169 and NEHC Rpt. 4121, Ser 34Bm/12187	RDM Multi-Enterprises, Inc. P.O. Box 179 Anaconda, MT 59711 Plant: 1/2 Mile East of Anaconda on Montana Highway #1 Anaconda, MT 59711

QPL-22262-18

GOVERNMENT DESIGNATION	MANUFACTURER'S DESIGNATION	TEST OR QUALIFICATION REFERENCE	MANUFACTURER'S NAME AND ADDRESS
	Black Beauty 1240 2040	NAVSHIPYD, MARE 9631, Ser 134.6/ 181 and NEHC Rpt. 6720, Ser 422hc/ 03299	Reed Minerals Div. Harsco Corporation 8149 Kennedy Avenue Highland, IN 46322 Plant: State Road 176 Drakesboro, KY 42337
	Black Beauty 1040 1243 2043	NAVSHIPYD, MARE Rpts. 9631, Ser 134.6/202 & Ser 134.6/ 224 & NEHC Rpt. 6720, Ser 34Bvs/11513	Reed Minerals Div. Harsco Corporation 8149 Kennedy Avenue Highland, IN 46322 Plant: River Rd. at Merrimack Power Station Concord (Bow), NH 03302
	Stan-Blast	NAVSHIPYD, MARE 9631, Ser 134.6/ 48 and NEHC Rpt. 6270, Ser 422c/ 08253	Stan-Blast Abrasives Company, Inc. 2525 South Shore Blvd. Suite 301 League City, TX 77573 Plant: 5712 Port Industrial Galveston, TX 77552
	Stan-Blast	NAVSHIPYD, MARE 9631, Ser 134.6/ 132 and NEHC Rpt. 6270, Ser 422c/ 08253	Stan-Blast Abrasives Company, Inc. 2525 South Shore Blvd. Suite 301 League City, TX 77573 Plant: 3300 River Road Harvey, LA 70059
	Black Blast	NAVSHIPYD, MARE 9631, Ser 134.6/ 11 and NEHC Rpt. 4121, Ser 34Bns/ 11017	Virginia Materials P.O. Box 7400 Norfolk, VA 23509 Plant: 3306 Peterson Street Norfolk, VA 23509

APPENDIX B

LISTING OF REGULATORY INFORMATION SOURCES

HAZARDOUS WASTE CONTACTS

ALABAMA
Alabama Dept of Environmental Management
Land Division
1751 Federal Drive
Montgomery, AL 36130
334-271-7730

ALASKA
Dept. of Environmental Conservation
410 Willoughby Avenue, Suite 105
Juneau, AK 99801-1795
Program Manager: 907-465-5150
Northern Regional Office (Fairbanks): 907-451-2360
South-Central Regional Office (Juneau): 907-563-6529
Southeast Regional Office (Juneau): 907-465-5350

ARIZONA
Arizona Dept. of Environmental Quality
Waste Programs Bureau
3033 North Central Avenue
Phoenix, AZ 85012
602-207-2300

ARKANSAS
Dept. of Pollution Control and Ecology
Hazardous Waste Division
P.O. Box 8913
8001 National Drive
Little Rock, AR 72219-8913
501-562-7444

CALIFORNIA
California EPA
Dept. of Toxic Substances Control
400 P Street, 4th Floor
P.O. Box 806
Sacramento, CA 95812-0806
916-322-0504

California EPA
State Water Resources Control Board
Water Resources Control Board
P.O. Box 100
Sacramento, CA 95812-0100
916-657-2390

COLORADO
Public and Environment Dept.
Hazardous Materials and Waste Management Division
4300 Cherry Creek Drive South
Denver, CO 80222
303-692-3300

CONNECTICUT
Dept. of Environmental Protection
Waste Management Bureau
Waste Engineering and Enforcement Division
79 Elm Street
Hartford, CT 06106
203-424-3023

Connecticut Resource
Recovery Authority
179 Allyn Street, Suite 603
Professional Building
Hartford, CT 06103
203-549-6390

DELAWARE
Dept. of Natural Resources and Environmental Control
Division of Air and Waste Management
Hazardous Waste Office
89 King's Highway
P.O. Box 1041
Dover, DE 19903
302-739-3689

DISTRICT OF COLUMBIA
Dept. of Consumer and Regulatory Affairs
Environmental Regulation Administration
Pesticides and Hazardous Waste Management Branch
2100 Martin Luther King Avenue, SE, Suite 203
Washington, DC 20020
202-645-6617

FLORIDA
Environmental Protection Dept.
Waste Management Division
Solid and Hazardous Waste Bureau
3900 Commonwealth Boulevard
Tallahassee, FL 32399
904-488-0300

GEORGIA
Georgia Dept. of Natural Resources
Environmental Protection Division
Hazardous Waste Management Branch
Floyd Towers East, Suite 1154
205 Butler Street, SE
Atlanta, GA 30334
404-656-7802

HAWAII
Dept. of Health
Solid and Hazardous Waste Branch
5 Waterfront Plaza, Suite 250
919 Ala Moana Boulevard
Honolulu, HI 96813
808-586-4225

IDAHO
Dept of Health and Welfare
Division of Environmental Quality
280 North 8th Street
Boise, ID 83720
208-334-5840

ILLINOIS

Energy and Natural Resources Dept.
Solid Waste and Renewable Resources Division
325 West Adams Street, Room 300
Springfield, IL 62704
217-785-2800

INDIANA
Dept. of Environmental Management
Office of Solid and Hazardous Waste
100 North Senate Avenue
Indianapolis, IN 46206
317-232-3210

IOWA
Dept. of Natural Resources
Waste Management Assistance Division
Wallace State Office Building
900 East Grand
DesMoines, IA 50319
515-281-8975

KANSAS
Dept. of Health and Environment
Bureau of Waste Management
Forbes Field, Building 740
Topeka, KS 66620
913-296-1612

KENTUCKY
Natural Resources and Environmental Protection Cabinet
Division of Waste Management
18 Reilly Road
Frankfort, KY 40601
502-564-4245

LOUISIANA
Dept. of Environmental Quality
Solid and Hazardous Waste Division
11720 Airline Highway
Baton Rouge, LA 70817
504-765-0249

MAINE
Dept. of Environmental Protection
Bureau of Hazardous Materials and Solid Waste Control
State House Station #17
Augusta, ME 04333
207-289-2651

MARYLAND
Environment Dept.
Waste Management Administration
2500 Broening Highway
Baltimore, MD 21201
410-631-3304

MASSACHUSETTS
Dept. of Environmental Protection
Hazardous Waste Division
One Winter Street, 5th Floor
Boston, MA 02108
617-292-5853

MICHIGAN
Michigan Dept. of Natural Resources
Waste Management Division
P.O. Box 30241
Lansing, MI 48909
517-373-2730

MINNESOTA
Pollution Control Agency
Hazardous Waste Division
520 Lafayette Road North
St. Paul, MN 55155
612-297-8502

MISSISSIPPI
Dept. of Environmental Quality
Division of Solid and Hazardous Waste Management
P.O. Box 10385
Jackson, MS 39289
601-961-5047

MISSOURI
Dept. of Natural Resources
Waste Management Program
P.O. Box 176
Jefferson City, MO 65102
314-751-3176
Missouri Natural Resources Hotline: 800-334-6946

MONTANA
Dept. of Health and Environmental Sciences
Waste Management Division
Cogswell Building, Room B 201
Helena, MT 59620
406-444-1430

NEBRASKA
Environmental Quality Dept.
P.O. Box 98922
Lincoln, NE 68509
402-471-2186

NEVADA
Conservation and Natural Resources Dept.
Division of Environmental Protection
Waste Management Program
123 West Nye
Carson City, NV 89710
702-687-4670

NEW HAMPSHIRE
Dept. of Environmental Services
Waste Management Division
Health and Welfare Building
6 Hazen Drive
Concord, NH 03301
603-271-3406

NEW JERSEY
Dept. of Environmental Protection and Energy
Solid Waste Management
401 East State Street, CN-423
Trenton, NJ 08625
609-530-8591

NEW MEXICO
Environmental Improvement Division
Hazardous Waste Bureau
P.O. Box 26110
Santa Fe, NM 87502
505-827-2775

NEW YORK
Dept. of Environmental Conservation
Division of Hazardous Substances Regulation
50 Wolf Road, Room 229
Albany, NY 12233
518-457-6934
SQG Hotline: 800-462-6553

NORTH CAROLINA
Dept. of Environmental, Health, and Natural Resources
Hazardous Waste Section
P.O. Box 27687
Raleigh, NC 27611
919-715-4140

NORTH DAKOTA
Dept. of Health
Consolidated Laboratories
Division of Waste Management
P.O. Box 5520
1200 Missouri Avenue, Room 302
Bismark, ND 58502
701-328-5166

OHIO
Ohio EPA
Division of Hazardous Waste
P.O. Box 1049
Columbus, OH 43216
614-644-2917

OKLAHOMA
Environmental Quality Dept.
Waste Management Division
1000 NE Tenth Street
Oklahoma City, OK 73117
405-271-7041

OREGON
Dept. of Environmental Quality
Hazardous Waste Division
811 SW. Sixth Avenue
Portland, OR 97204
503-229-6585

PENNSYLVANIA
Dept. of Environmental Resources
Bureau of Waste Management
Director's Office
P.O. Box 2063
Harrisburg, PA 17105
717-787-9870

RHODE ISLAND
Dept. of Environmental Management
Division of Air and Hazardous Materials
291 Promenade Street
Providence, RI 02908
401-277-4700

SOUTH CAROLINA
Dept. of Health and Environmental Control
Bureau of Solid and Hazardous Waste Management
2600 Bull Street
Columbia, SC 29201
803-734-5202

SOUTH DAKOTA
Dept. of Environment and Natural Resources
Office of Waste Management
500 East Capital Avenue
Pierre, SD 57501
605-773-3351

TENNESSEE
Environment and Conservation Dept.
Solid Waste Management Division
401 Church Street, 21st Floor
Nashville, TN 37248
615-532-0780

TEXAS
Natural Resource Conservation Commission
Industrial and Hazardous Waste Division
P.O. Box 13087
Capital Station
Austin, TX 78711
512-239-2324

UTAH
Dept. of Environmental Quality
Division of Solid and Hazardous Waste
P.O. Box 144810
Salt Lake City, UT 84114
801-538-6170

VERMONT
Natural Resources Agency
Environmental Conservation Dept.
Hazardous Material Division
103 South Main Street
Waterbury, VT 05676
802-241-3888

VIRGINIA
Natural Resources Office
Environment Quality Dept.
629 East Main Street
Richmond, VA 23219
804-762-4020
Hazardous Waste Hotline: 800-552-2075

WASHINGTON
Dept. of Ecology
Solid and Hazardous Waste Program
P.O. Box 47600, Row 6, Building 4
Olympia, WA 98504
360-407-6103

WEST VIRGINIA
Environmental Protection Bureau
Waste Management Division
1356 Hansford Street
Charleston, WV 25301
304-558-5929

WISCONSIN
Dept. of Natural Resources
Solid and Hazardous Waste Management
P.O. Box 7921
Madison, WI 53707
608-266-1327

WYOMING
Dept. of Environmental Quality
Solid Waste Management Division
Herschler Building
122 West 25th Street
Cheyenne, WY 82002
307-777-7752

ADDITIONAL SOURCES OF INFORMATION

1. **Phone & Hotline Information**
   - RCRA/Superfund Hotline
     1-800-424-9346 (in Washington, DC 260-3000)
   - EPA Small Business Ombudsman Hotline
     1-800-368-5888 (in Washington, DC 557-1938)
   - National Response Center
     1-800-494-8802 (in Washington, DC 260-2675)
   - Transportation of Hazardous Materials
     202-366-4488
   - Toxic Substance Control Act (TSCA) Assistance Service
     202-554-1404
   - Center for Hazardous Materials Research (CHMR) Hotline
     1-800-334-2467
2. **EPA Documents**
   - EPA/530-SW-86-019, September 1986, *Understanding the Small Quantity Generator, Hazardous Waste Generator.*
   - EPA/530-SW-037, November 1986, *Solving the Hazardous Waste Problem — EPA's RCRA Program.*
3. ***Journal of Protective Coatings & Linings*** (available from Technology Publishing Co., 2300 Wharton St., Suite 310, Pittsburgh, PA 15203 [800-837-8303])
4. **Other Publications**
   - *Bridge Paint Removal, Containment & Disposal,* Synthesis Report 20-05/20-09, 1992. Transportation Research Board, 2101 Constitution Ave., Washington, DC 20418
   - *Removal of Lead-Based Bridge Paints,* NCHRP Report 265, December 1983, Transportation Research Board.
   - *Industrial Lead Paint Removal Handbook,* SSPC 91-18, November 1991. Available from SSPC, 4400 Fifth Ave., Pittsburgh, PA 15213.

APPENDIX C

THE USE OF RECYCLABLE MATERIALS IN ASPHALT CONCRETE AND CONCRETE USE CONSTITUTING DISPOSAL OR UCD

HAZARDOUS WASTE MANAGEMENT PROGRAM

MANAGEMENT MEMO

MANAGEMENT MEMO #: EO-95-010-MM

TITLE: USE CONSTITUTING DISPOSAL

AFFECTED PROGRAMS: Hazardous Waste Management Program
Site Mitigation Program

ISSUE:

The Department of Toxic Substances Control (DTSC) is now developing regulations to address the "use constituting disposal" restriction as it pertains to recyclable materials that are non-RCRA hazardous wastes in section 25143.2(e)(2) of the Health and Safety Code (HSC). A "non-RCRA" waste is hazardous waste that is regulated in California but is not a Resource Conservation and Recovery Act (RCRA) waste. A RCRA hazardous waste is any waste identified as a hazardous waste in Part 261, Subchapter I, Chapter 1 of Title 40 of the Code of Federal Regulations (40 CFR). The "use constituting disposal" restriction affects the eligibility of recyclable materials for the exclusions and exemptions provided under HSC section 25143.2. The purpose of this management memo is to provide interim guidance on how to interpret "use constituting disposal," and therefore determine if a waste is subject to regulation pursuant to HSC section 25143.2(e)(2), until the regulations are adopted.

BACKGROUND:

HSC section 25143.2 addresses exclusions and exemptions for recyclable materials that are managed in a specified manner. Note that a recyclable material is defined as a hazardous waste that is capable of being recycled.[1] HSC section 25143.2 also lists conditions under which the recyclable materials must be fully regulated as hazardous wastes, regardless of the exclusions from classification as a waste and the exemptions from facility permitting requirements granted in this section. One such condition is when the materials are "used in a manner constituting disposal." This restriction is addressed separately for RCRA wastes and non-RCRA wastes.

Under California law, there is no definition for "use constituting disposal." The U.S. Environmental Protection Agency (U.S. EPA) has defined "use constituting disposal" to mean placing recyclable materials or products derived from recyclable

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[1] Ref. HSC section 25120.5.

materials on the land.[2] Under federal regulations, recyclable materials that are used in a manner constituting disposal are subject to regulation as solid wastes. At the same time, the U.S. EPA does not currently regulate products containing recyclable materials that are placed on the land if the recyclable materials have undergone a chemical reaction in producing the product so as to be physically inseparable from the product and the product meets the applicable treatment standards (or applicable prohibition levels where no treatment standards have been established) in subpart D, part 268, 40 CFR.

Since 1987, the DTSC has applied a set of criteria to recyclable materials placed on the land in determining whether or not such materials are "used in a manner constituting disposal." If these criteria are met, the recyclable materials are not regulated pursuant to HSC section 25143.2(e)(2) and may be eligible for the exclusions and exemptions under HSC section 25143.2 (b), (c) or (d). **The DTSC's criteria apply only to non-RCRA wastes.** The DTSC is currently writing regulations to address the issue of recyclable materials that are placed on the land ("use constituting disposal"). This management memo clarifies the criteria applied by the DTSC pending adoption of these regulations.

ACTION:

The following, **which applies only to non-RCRA wastes**, is the DTSC's present interpretation of the "use constituting disposal" restriction, i.e., of which recyclable materials are subject to regulation, in HSC section 25143.2(e)(2). This interpretation applies only until regulations addressing recyclable materials used in a manner constituting disposal or placed on the land are adopted.

A recyclable material that is placed on the land or used to produce a product which is placed on the land is regulated pursuant to HSC section 25143.2(e)(2) unless all applicable criteria listed below are met.

1. This criterion applies to situations where the recyclable material is used as an ingredient in the manufacture of a product. Hazardous constituents in the recyclable material whose concentrations are greater than or equal to the

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[2] Ref. 50 Federal Register 618, January 4, 1985, and 40 CFR 266.20.

regulatory Soluble Threshold Limit Concentrations (STLCs)[3] shall have chemically reacted or become physically bound so as not to leach from the product containing the recyclable material. Specifically, the hazardous constituents shall not leach out in concentrations that would exceed the applicable STLC, once the effect of dilution by other ingredients (as explained below) has been taken into account.

In order to meet this requirement, the following procedures must be used to evaluate the recyclable material and the product:

(a) Sampling and analysis:

(1) Sampling shall be conducted according to the sampling methods described in Test Methods for Evaluating Solid Waste, Physical/Chemical Methods, SW-846, 3rd edition, 1986, or one of the sampling methods listed in Appendix I, Chapter 11, Division 4.5, Title 22, California Code of Regulations (22 CCR); and

(2) Analysis shall be conducted according to the Waste Extraction Test (WET), Appendix II, Chapter 11, Division 4.5, 22 CCR, or an alternative test method approved pursuant to 22 CCR section 66260.21

(b) In order to demonstrate that the hazardous constituents in the recyclable material are bound in the product so that they would not exceed the applicable STLC, even when eliminating the effect of dilution by other ingredients, the following calculations must be used.

The concentration of the hazardous constituents in the final product, as determined by the WET, must be multiplied by the dilution factor inherent in combining the recyclable material with other materials. The dilution factor is calculated by dividing the weight of the final product made with the recyclable material by the weight of the recyclable material used in the product, or

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[3] As set forth in sections 66261.24(a)(2)(A) and (a)(2)(B), Division 4.5, Title 22 of the California Code of Regulations (22 CCR).

$$\frac{\text{weight of final product}}{\text{weight of recyclable material}} = \text{dilution factor}$$

If the ingredients in the product that are not recyclable materials contain the same hazardous constituents present in the recyclable material, the hazardous constituents in the ingredients that are not recyclable materials may be subtracted from the concentration of hazardous constituents in the final product, adjusted for dilution.

The final calculation of the hazardous constituents present in the product, as determined by taking into account the effects of dilution and, where applicable, the effects of hazardous constituents in ingredients that are not recyclable materials, must be less than the applicable STLC.

The following is an example of how these calculations can be done.

A ton of spent sandblast grit, which is hazardous due to a mean soluble lead concentration of 12 mg/L, is combined with nineteen tons of other aggregate and asphalt to produce twenty tons of asphaltic concrete. The dilution factor is thus 20 (twenty tons of final product, including the recyclable material, divided by the original one ton of recyclable material). The asphaltic concrete is then subjected to the WET and yields mean results for lead of 0.05 mg/l. This number is then multiplied by the dilution factor, 20, for a result of 1.00 mg/l. The aggregate that is not a recyclable material was tested with the WET and found to have a concentration of 0.05 mg/l lead. This concentration can be subtracted from 1 mg/l to give you 0.95 mg/l. This final calculation does not exceed the STLC for lead of 5 mg/l and therefore meets the criterion.

2. A recyclable material used as a substitute for a commercial product or a product containing a recyclable material shall not contain constituents that cause the product to exhibit hazardous characteristics pursuant to Chapter 11, Division 4.5, CCR 22, other than those constituents that are also found in the same or greater concentrations in a comparable commercial product. The only exception to this requirement is if the person claiming an exclusion obtains

the DTSC's written concurrence prior to using the recyclable material that:

(a) the concentrations of hazardous constituents greater than those present in a comparable commercial product improve the quality of the product made from the recyclable material and do not increase the hazards to public health or the environment of that product; or

(b) if no comparable commercial product exists, the hazardous constituents in the recyclable material that cause the product to exhibit a characteristic of a hazardous waste are beneficial to the product and do not cause the product to pose a threat to public health or the environment.

3. The recyclable material must be used beneficially, as demonstrated by both of the following conditions:

   (a) Prior to use, the recyclable material and the product containing that material must each be certified by a qualified independent engineer registered in the state of California[4] to meet the applicable standards or specifications for the intended use of the recyclable material or product of the American Society for Testing and Materials (ASTM), the American Association of State Highway and Transportation Officials (AASHTO), the American National Standards Institute (ANSI), the Uniform Building Code (UBC), or the standards of a government agency having jurisdiction over the construction applications of that recyclable material or product. A nationally recognized industry standard, other than those mentioned, may be used with the prior written approval of the DTSC.

   (b) There shall be no indications of sham recycling, including, but not limited to, use of the recyclable material or a product containing a recyclable material in excess of what is necessary to accomplish its function, handling of the recyclable material in a manner inconsistent with the economic value of the

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[4] By "qualified independent engineer", we mean an engineer whose registration (e.g., civil, mechanical, structural, etc.) is appropriate for the product she/he is certifying and who is not an employee of the person claiming an exclusion or exemption pursuant to HSC 25143.2.

material, or insufficient use of the recyclable material to accomplish its function.

Non-RCRA hazardous wastes managed according to the applicable criteria above will not be regulated pursuant to HSC 25143.2(e) and may therefore qualify for the exclusions and exemptions in HSC section 25143.2 if the requirements of a specific exclusion or exemption are met and none of the other provisions of subdivision (e) apply.

Examples of recyclable materials used in products placed on the land are spent sandblast grit, contaminated soils, foundry sands, ash, and demolition wastes, which may be used, among other things, as asphalt treated road base, landfill cover material, or aggregate in Portland cement concrete or an asphaltic concrete.

Use of recyclable materials as fertilizer, soil amendment, agricultural mineral, or an auxiliary soil and plant substance, with or without combination with other materials, is not covered by this management memo and is regulated separately.[5] Used oil is also not covered by this management memo.[6]

This management memo will stay in effect until the promulgation of regulations regarding management requirements for recyclable materials that are placed on the land, i.e., used in a manner constituting disposal, or until it is replaced by a subsequent management memo or DTSC policy.

DISTRIBUTION:

Cal/EPA Access Bulletin Board System
Hazardous Waste Management Program Policy Mailing List

ATTACHMENTS: None

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[5] Ref. Article 8, Chapter 16, 22 CCR.

[6] Ref. Article 13, Chapter 6.5, Division 20 of the Health and Safety Code.

CONTACT:

Ms. Jessie Schnell
Resource Recovery Section
State Regulatory Program Division
Hazardous Waste Management Program HQ-10
Department of Toxic Substances Control
P.O. Box 806
Sacramento, California 95812-0806
Phone: (916)322-1003/CALNET 492-1003

8/18/95
Date

Ted N. Raul
Ted N. Rauh
Deputy Director

Tampa, Fla.

HISTORICAL WEATHER DATA

Average Temperature

	Year	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
°F	**72.4**	59.9	61.5	66.6	71.3	77.4	81.3	82.4	82.4	80.9	74.8	67.5	62.2
°C	**22**	15	16	19	21	25	27	28	28	27	23	19	16

Years Charted: 30
Results based on data collected from 1961 - 1990

Source: National Weather Service, San Francisco

Average High Temperature

	Year	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
°F	**81.6**	69.8	71.4	76.6	81.7	87.2	89.5	90.2	90.2	89	84.3	77.7	72.1
°C	**27**	21	21	24	27	30	31	32	32	31	29	25	22

Years Charted: 30
Results based on data collected from 1961 - 1990

Source: National Weather Service, San Francisco

Average Low Temperature

	Year	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
°F	**63**	50	51.6	56.5	60.8	67.5	72.9	74.5	74.5	72.8	65.2	57.2	52.3
°C	**17**	10	10	13	16	19	22	23	23	22	18	14	11

Years Charted: 30
Results based on data collected from 1961 - 1990

Source: National Weather Service, San Francisco

Average Wind Speed

	Year	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
mph	**8.3**	8.6	9.2	9.4	9.2	8.7	7.9	7.1	6.9	7.7	8.4	8.4	8.4
km/h	**13**	13	14	15	14	13	12	11	11	12	13	13	13

Years Charted: 47 **Source:** National Weather Service, San Francisco
Results based on data collected through 1993

Average Days of Precipitation

	Total	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
Days	**106**	7	7	7	5	6	12	16	17	13	7	5	6

Years Charted: 47 **Source:** National Weather Service, San Francisco
Results based on data collected through 1993

Days With Sunshine

	Year	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
%	**66**	63	66	71	75	75	67	62	61	61	65	64	62

Years Charted: 46 **Source:** National Weather Service, San Francisco
Results based on data collected through 1993

Mean Number of Cloudy Days

	Total	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
Days	**121**	12	10	10	8	8	10	12	11	11	9	9	11

Years Charted: 47 **Source:** National Weather Service, San Francisco
Results based on data collected through 1993

Mean Number of Partly Cloudy Days

	Total	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
Days	**143**	10	9	10	11	12	14	16	17	14	10	9	10

Years Charted: 47 **Source:** National Weather Service, San Francisco
Results based on data collected through 1993

Highest Recorded Temperature

	Year	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
°F	**99**	86	88	91	93	98	99	97	98	96	94	90	86
°C	**37**	30	31	32	33	36	37	36	36	35	34	32	30

Years Charted: 47 **Source:** National Weather Service, San Francisco
Results based on data collected through 1993

Lowest Recorded Temperature

	Year	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
°F	**18**	21	24	29	40	49	53	63	67	57	40	23	18
°C	-7	-6	-4	-1	4	9	11	17	19	13	4	-5	-7

Years Charted: 47 **Source:** National Weather Service, San Francisco
Results based on data collected through 1993

Mean Number of Days Below 32°F/0°C

	Total	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
Days	3	2	1	---	0	0	0	0	0	0	0	---	1

Years Charted: 30 **Source:** National Weather Service, San Francisco
Results based on data collected through 1993

Average Precipitation

	Year	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
in.	**43.92**	1.99	3.08	3.01	1.15	3.1	5.48	6.58	7.61	5.98	2.02	1.77	2.15
mm	**1115**	50	78	76	29	78	139	167	193	151	51	44	54

Years Charted: 30 **Source:** National Weather Service, San Francisco
Results based on data collected from 1961 - 1990

Average Snowfall

	Year	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
in.	**0**	0	0	0	0	0	0	0	0	0	0	0	0
mm	**0**	0	0	0	0	0	0	0	0	0	0	0	0

Years Charted: 47 **Source:** National Weather Service, San Francisco
Results based on data collected through 1993

Mean Number of Clear Days

	Total	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
Days	**102**	9	9	11	11	11	6	3	3	5	12	12	10

Years Charted: 47 **Source:** National Weather Service, San Francisco
Results based on data collected through 1993

Average Morning Relative Humidity

	Year	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
%	**88**	87	86	87	87	86	87	87	90	91	89	88	87

Years Charted: 30 **Source:** National Weather Service, San Francisco
Results based on data collected through 1993

Average Afternoon Relative Humidity

	Year	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
%	**58**	59	56	55	51	52	60	63	64	61	57	57	59

Years Charted: 30 **Source:** National Weather Service, San Francisco
Results based on data collected through 1993

Questions? Comments? Suggestions? E-mail weather@weatherpost.com.

INSTRUCTIONS

FORM 2.8 STORAGE PILE WORKSHEET

This form is **REQUIRED** if a facility is reporting emissions from one or more open storage piles that are on the facility site.

Due to an APCP policy change in March 1998, the methodology for calculating storage pile emissions has been modified. There are now two different categories of emissions from storage piles: **(1) activity and (2) wind erosion**. The activity portion of storage pile emissions submittals includes the vehicle activity and load in/load out components and are calculated in the same manner as in previous EIQs. The wind erosion component is now calculated using pile area **(acres)** instead of **tons** stored as the throughput.

The rationale for the separation of these two categories is the physical difference in the nature of emissions from storage piles. Load in/load out and vehicle activity emissions are generated by human activity around the pile and can be represented by tons stored in the pile. However, wind erosion emissions can occur without disturbance of the pile and only occur during specific meteorological conditions.

With the use of the revised methodology, two different Source Classification Codes (SCC) are required. For quarry and associated industry storage piles, use SSC No. 3-05-020-07, Stone Quarrying, Open Storage (lb/ton) with activity emissions and use SCC No. 3-05-025-07, Sand/Gravel Storage Piles (lb/acre) with wind erosion emissions. **This will require the use of two emission point information forms (Form 2.0) for each different type of storage pile but point number should be the same.** Assign an activity SCC associated with a pound per ton emission factor to one Form 2.0 and a wind erosion SCC associated with a pound per acre emission factor to the other.

If you want to continue using SCC No. 3-05-020-07 with the default PM_{10} emission factor of 0.12 lb/ton for all storage pile emissions, complete all the information for Block 1, STORAGE PILE INFORMATION. If you are not using SCC emission factors, fill out this document completely.

Use Form 2.8 to derive two emission factors for each storage pile, using various criteria inputs. When calculating the PM_{10} emission factor for a storage pile, the following instructions apply.

Use a separate Form 2.8 for each storage pile emission point identified on Form 1.1, Process Flow Diagram and Form 1.2, Summary of Emission Points.

You may group and report separate storage piles as one point if they meet certain conditions: a) the physical characteristics of the pile and the surrounding environment are so similar that, if you calculate separate emission factors, the results would be the same; or b) the physical characteristics of the piles and the characteristics of the surrounding environment are so different that if you calculated emission factors for each pile, the results would not be equal. In this case, the reported emission factor will be the weighted average of the emission factor for each pile.

4

STATE OF MISSOURI
DEPARTMENT OF NATURAL RESOURCES
AIR POLLUTION CONTROL PROGRAM
205 JEFFERSON STREET, P.O. BOX 176
JEFFERSON CITY, MISSOURI 65102

EMISSIONS INVENTORY QUESTIONNAIRE (EIQ)

FORM 2.8 STORAGE PILE WORKSHEET

SHADED AREAS FOR OFFICE USE ONLY

FACILITY NAME	FIPS COUNTY NO.	PLANT NO.	YEAR OF DATA

[1] STORAGE PILE INFORMATION

POINT NO.	AIRS ID-PT	SCC	SEG NO.	TYPE OF MATERIAL STORED Coal slag / Spent ABD

MOISTURE CONTENT (%): 0.4 (DEFAULT = .07%)

SILT CONTENT: 10 (DEFAULT = 1.6%)

STORAGE DURATION (DAYS):

ANNUAL AMOUNT STORED (TONS):

MAXIMUM HOURLY AMOUNT STORED: ~~[illegible]~~ 550 TPH

AREA OF STORAGE PILE (ACRES): 0.03 per pile

RAW MATERIAL LOADING METHOD (CHECK ONE)
☐ BARGE
☐ RAIL
☐ TRUCK
☐ CONVEYOR
☐ OTHER (SPECIFY)

RAW MATERIAL UNLOADING METHOD (CHECK ONE)
☐ BARGE
☐ RAIL
☐ TRUCK
☐ CONVEYOR
☐ OTHER (SPECIFY)

[2] OTHER FACTORS AFFECTING EMISSION RATES

MEAN WIND SPEED (MPH): 8.3 (DEFAULT = 10 MPH)

% OF TIME WIND > 12 MPH: 32% (DEFAULT = 32%)

DRY DAYS PER YEAR: 260 (DEFAULT = 260 DAYS)

VEHICLE ACTIVITY FACTOR: 1 (DEFAULT = 1.0)

[3] STORAGE PILE EMISSION FACTOR CALCULATIONS

[3-A-1] LOAD IN-LOAD OUT COMPONENT =

.00224 X ({MEAN WIND SPEED} / 5)^1.3 / ({MOISTURE CONTENT (%)} / 2)^1.4

LOAD IN-LOAD OUT COMPONENT: ~~[illegible]~~ 0.0412

[3-A-2] VEHICLE ACTIVITY COMPONENT =

0.05 X ({SILT CONTENT (%)} / 1.5) X ({DRY DAYS PER YEAR} / 235) X {VEHICLE ACTIVITY FACTOR}

0.05 x (10/1.5) x ((260/235) x 1)

VEHICLE ACTIVITY COMPONENT: 0.369

[3-B] WIND EROSION COMPONENT =

0.85 X ({SILT CONTENT (%)} / 1.5) X ({STORAGE DURATION (DAYS)}
X ({DRY DAYS PER YEAR} / 235) X ({% OF TIME WIND > 12MPH} / 15) LB/ACRE

WIND EROSION COMPONENT: 0.53 lb/acre per day

[4] STORAGE PILE PM10 EMISSION FACTOR

ACTIVITY PM10 EMISSION FACTOR =
{[3-A-1] LOAD IN-LOAD OUT COMPONENT} + {[3-A-2] VEHICLE ACTIVITY COMPONENT}

[4-A] ACTIVITY PM10 EMISSION FACTOR: 0.41 ~~[illegible]~~ lb PM10 / ton LB PM10/TON

[4B] WIND EROSION PM10 EMISSION FACTOR: LB PM10/ACRE

PLEASE NOTE

IF YOU USE A SOURCE CLASSIFICATION CODE (SCC) NUMBER AND EMISSION FACTOR FROM THE LIST IN THE INSTRUCTIONS FOR THIS FORM, MAKE SURE TO COMPLETE BLOCK 1, STORAGE PILE INFORMATION FOR EACH STORAGE PILE.

DUPLICATE THIS FORM AS NEEDED.

Activity Emission Factor Example: Suppose a facility has three distinct storage piles with annual throughputs of 100,000, 200,000 and 500,000 tons, respectively. Also assume the respective calculated PM_{10} activity emission factors are .18, .135 and .165 lbs/ton of material stored.

100,000 tons x .18 lbs/ton = 18,000 lbs.
200,000 tons x .135 lbs/ton = 27,000 lbs.
500,000 tons x .165 lbs/ton = 82,500 lbs.
800,000 tons 127,500 lbs.

127,500 lbs. PM_{10}) 800,000 tons = .1594 lbs. PM_{10} /ton.

You would enter this weighted average result of .1594 on Form 2.0 for the activity portion as the emission factor for the point.

Complete Facility Name, County Number, Plant Number and Year of Data.
See Form 1.0 instructions, page 1.0-1.

1) STORAGE PILE INFORMATION

Point Number: This number is the unique identification number for each specific storage pile. This identification number must match the point number entered on Form 1.1, Process Flow Diagram; Form 1.2, Summary of Emission Points; and Form 2.0, Emission Point Information.

NOTE: Again, using the revised approach, there will be two Form 2.0 completed but the same point number will be used for each storage pile or group (one for activity and one for wind erosion).

SCC Number for Activity: List the SCC in tons that identifies the type of storage material for activity emissions.

SCC Number for Wind Erosion: List the SCC in **acres** that identifies the type of storage material for wind erosion emissions.

Type of Material Stored: Enter the type of material in the open storage pile for this emission point. Examples of some common storage pile materials include gravel, fines, pea gravel, crushed stone dust, crushed cinder, etc.

Moisture Content of Stored Material: Enter the moisture content of the storage pile if known. For examples, refer to Table 13.2.4-1 or Table 2.1.2-2 at the end of this instruction set. You may use a default value of 0.7% for the moisture content of the storage pile if no other information is available.

Use the moisture content percentage, not the decimal equivalent, when calculating the Load In-Load Out Factor in Section 3-A. Example: If the default value of 0.7% is selected, enter as .7 in the formula.

Area of Storage Piles: Estimate the number of acres of land that is under this specific storage pile.

Silt Content: Enter the Silt Content of the storage pile if known. Calculate the Silt Content by measuring the proportion of dry aggregate material that passes a 200 mesh screen, using ASTM-C-136 method. The Silt Content for some common materials stored in open storage piles are listed in Table 13.2.4-1 and Table 2.1.2-2. You may use a default value of 1.6% may be used for the storage pile if no other information is available.

Use the Silt Content percentage, not the decimal equivalent, when calculating the Wind Erosion and Activity Factors in Section 3-B and 3-C.
Example: If the default value of 1.6% is selected, enter as 1.6 in the formula.

Storage Duration: Enter the average number of days per year that aggregate material remains in the storage pile. Table 2.1.2-2 lists some estimates on the storage duration for various types of storage material.

Annual Amount Stored: Enter the total amount of all aggregate material produced and subsequently stored in the storage pile during the year. Enter tons of material stored per year.

Maximum Hourly Amount Stored: List the largest quantity of aggregate stored at any time during the last calendar year. Enter the maximum number of tons of material stored.

Raw Material Loading Method: Check the box that best corresponds to the main method of loading or removing material from the storage pile.

Raw Material Unloading Method: Check the box that best corresponds to the main method of unloading or adding material to the storage pile.

2) OTHER FACTORS AFFECTING EMISSION RATES

Mean Wind Speed: The statistical mean of all wind speeds at a height 10 centimeters above the storage piles, regardless of the wind direction. You may use a default value of 10 miles per hour for the Mean Wind Speed figure.

Percent of Time the Wind Velocity is Greater than 12 MPH:
The percent of time that the unobstructed wind velocity exceeds 12 miles per hour at the mean pile height. You may use a default value of 32%.

Dry Days Per Year: The number of days that at least 0.01 inches of rain did not fall. You may use a default value of 260 days.

Vehicle Activity Factor: Use the following table to select the correct value for VAF (Vehicle Activity Factor) for this storage pile. You may use a default value of 1.0.

MATERIAL	VAF VALUE
Coal	0.08
Coke	0.25
Gravel	0.25
Iron Ore	0.06
Limestone	0.25
Sand (Fines)	1.00
Slag	1.00
Top Soil (Overburden)	0.25
All Others	1.00

3) STORAGE PILE EMISSION FACTOR CALCULATIONS

A.1 LOAD IN-LOAD OUT FACTOR

The Load In-Load Out factor is a calculated number that represents the amount of PM_{10} emissions that will result from the Load In-Load Out process. Use this formula to calculate the factor:

Load In-Load Out Factor =
0.00224 x (Mean Wind Speed) 5)^1.3) [Moisture Content (%)) 2]^1.4 lb/ton
(The Values 1.3 and 1.4 are exponents).

Perform the calculation for the Load In-Load Out Factor and enter the results in Block 3-A.1 of this form.

A.2 VEHICLE ACTIVITY FACTOR

The Activity Factor is a calculated number that represents the amount of PM_{10} released into the atmosphere due to vehicular traffic around the storage pile. Use this formula to calculate the factor:

Activity Factor =
0.05 x [Silt Content (%)) 1.5] x (Dry Days per Year) 235)
x (Vehicle Activity Factor) lb/ton

Perform the calculation for the Activity Factor and enter the results in Block 3-A.2 of this form

B. WIND EROSION PORTION FACTOR

The Wind Erosion Factor is a calculated number that represents the amount of PM_{10} released into the atmosphere from this storage pile due to wind erosion. Use this formula to calculate the factor:

Wind Erosion Factor =
0.85 x [Silt Content (%)) 1.5] x Storage Duration (Days)
x (Dry Days per Year) 235) x [(% of Time Wind > 12 MPH)) 15] lb/acre

Perform the calculation for the Wind Erosion Factor and enter the results in Block 3-B of this form.

4) COMBINED ANNUAL STORAGE PILE PM_{10} EMISSION FACTORS

(A) Add the Load In-Load Out Factor (3-A.1), and Vehicle Activity Factor (3-A.2) together and enter the result in Block 4-A of this form. When using this worksheet, always express the units as pounds of PM_{10} emitted per ton of aggregate stored in piles.

(B) Enter the result of the calculation in Block 3-B. When using this worksheet, always express wind erosion units in pounds of PM_{10} per acre of storage.

ENTER THE FOLLOWING ON FORM 2.0, EMISSION POINT INFORMATION FOR <u>THE ACTIVITY</u> PORTION OF STORAGE PILE EMISSIONS:

Block 1 - Enter the <u>SCC</u>. If you use the default SCC, enter **3-05-020-07 (lb/ton).**

Block 7 - Enter the combined <u>Activity PM_{10} Emission Factor</u> (Block 4-A) for this storage pile in the appropriate box.

ENTER THE FOLLOWING ON A SEPARATE FORM 2.0, EMISSION POINT INFORMATION FOR THE WIND EROSION PORTION OF STORAGE PILE EMISSIONS:

Block 1 - Enter the SCC. If you use the default SCC, enter **3-05-025-07 (lb/acre).**

Block 7 - Enter the Wind Erosion PM_{10} Emission Factor (Block 4-B) for this storage pile in the appropriate box.

Virginia Materials and Supplies, Inc.
3306 Peterson Street~Norfolk, VA 23509
Phone (757) 855-0155~ Fax (757) 857-5631
Email jb@sandblaster.com

Material Safety Data Sheet
(Complies with 29 CFR 1910.1200)

Section I - General

Virginia Materials & Supplies, Inc. (VMS)
T/A Virginia Materials
3306 Peterson Street
Norfolk, VA 23509

EMERGENCY TELEPHONE NUMBERS:
(757) 855-0155
(800) 793-0094

Product Name: "Black Blast" Abrasives

CAS Number:	68476-96-0 Particles not otherwise **regulated**
Common Name:	Slag, Coal
Date:	May 1995

SECTION II - Ingredients

Slag, Coal 99% - 100%

		OSHA *PEL	ACGIH *TLV
Nuisance Dust			
Total Dust	:	15	10
Respirable Dust	:	5	5

*Values Expressed as mg/M3

SECTION III - Physical Data

Physical Form:	Solid (angular granules)	**Boiling Temperature:**	N/A	**Melting Point:**	Greater than 2300 F
Vapor Pressure/Density:	N/A	**Evaporation Rate:**	N/A	**Specific Gravity:**	2.7 g/cc (typical)
Water Solubility:	Negligible	**Color:**	Black	**Odor:**	None

SECTION IV - Fire and Explosion Data

Product is nonflammable and nonexplosive.

SECTION V - Reactivity Data

Product is stable under normal conditions of use, storage and transportation.

SECTION VI - Health Hazard Data

Low health risk by inhalation. Treat as a nuisance dust. Typical free silica less than 0.1%. This material is not a recognized carcinogen or cocarcinogen. Human toxic response has not been demonstrated for any route of entry. Mechanical irritation may occur to eyes, skin or respiratory tract. Pre-existing health conditions may be aggravated.
Carcinogenicity: NTP - no; IARC Monographs - no; OSHA Regulated - no.

FIRST AID:

In case of:
1. Eye contact - Immediately flush eyes thoroughly with water or an opthalmic saline solution.
2. Skin contact - Wash skin with soap and water if irritation occurs.
3. Inhalation - Remove affected person(s) to fresh air source.
4. Oral Intake - Rinse mouth with water.

IF SYMPTOMS PERSIST CONTACT PHYSICIAN OR OTHER MEDICAL PERSONNEL.

SECTION VII - Spill, Leak and Disposal Procedures

No special procedures required for clean-up. Wetting with water will reduce airborne dust. Uncontaminated product does not exceed Toxicity Characteristic Leaching Procedure (TCLP) limits and may be disposed of as an inert material in an appropriate solid waste landfill according to applicable Federal, State and Local regulations.

SECTION VIII - Control Measures

Use appropriate NIOSH certified respiratory protection when exposure limits may be exceeded. Maintain sufficient ventilation to allow visual contact with work surfaces. Appropriate abrasive blaster's protective equipment is required, which may also include gloves, hood with protective lens, safety glasses and hearing protection.

SECTION IX - Special Precautions

Keep product dry and free of all contamination to assure free flow. Use an appropriate safety screen over fill hatch of blasting pot. Respirable dust may be generated during pressure abrasive cleaning operations.

NOTE

The opinions expressed herein are those of qualified experts within Virginia Materials & Supplies, Inc. (VMS). VMS believes that the information contained herein is current and accurate for the normal and intended use of this product as of the date of the Material Safety Data Sheet. Since the use of this information and of those opinions or the conditions of use of the product are not within the control of Virginia Materials & Supplies Inc., it is the user's obligation to determine and observe the conditions of safe use and disposal of the product by their operations.

Revised 08/2/99 Supercedes 5/12/99

STATE OF FLORIDA DEPARTMENT OF TRANSPORTATION
AGGREGATE SYSTEM
FINE AGGREGATE CODE FORM

SOURCE IDENTIFICATION

PROJECT NO. ______ PAY ITEM NO. ______ MATERIAL NO. ______

SAMPLE NO. 1 LAB NO. 1 TESTED BY PDPG DATE SAMPLED 02/22/01

SAMPLED BY FRANK M. DATE TESTED 02/23/01 SOURCE NO. (MINE/TERMINAL) ______ MINE NO. ______

MATERIAL IDENTIFICATION

MATERIAL CODE ______ MATERIAL TYPE ______ SAMPLE TYPE ______ SAMPLED FROM ______

PROCESS ______

INFORMATION ______

TEST RESULTS

FM ______ TARGET FM ______ PASS 200 10.26 APPARENT 2.815

______ TYPE GV ______ MOISTURE CONTENT 0.4% ABSORP. 0.4%

% CARB ______ MOD L.A. ______ SPGR(DRYBULK) 2.786 MOD GRAD ______

BULK(SSD) 2.796 DES MIX ______

ASPHALT / CONCRETE PLANT NO. ______

REMARKS NFCT MATERIAL

SAMPLE WT. 411.5 gms/lbs -DRY WT 381.4 = loss 30.1 + PAN WT. 12.1

WEIGHT (WT.)

%-200=[(Origional Dry Wt. -Dry Wt. After Washing)+Minus 200 Mateial From Dry Sieving] x 100/origional Dry Wt.

Gradation 411.5

SIZ	SIEVE SIZE	ACCUM WT.		% WEIGHT	% RETAINED		% PASSING	REMARKS
1	3/8"-9.5mm	0.0		0.0%	0.0%		100.0%	
2	No.4-4.75mm	2.6		0.6%	0.6%		99.4%	
3	No.10-2.00mm	5.7		1.4%	1.4%		98.6%	
4	N0.40-425um	179.1		43.5%	43.5%		56.5%	
5	N0.80-180um	296.9		72.2%	72.2%		27.8%	
6	NO.100-150M	320.2		77.8%	77.8%		22.2%	
7	NO.200-75MV	368.40		89.5%	89.5%		10.5%	
TOTAL WEIGHT		380.50						

6

TYPICAL CHEMICAL ANALYSIS
BLACK SAND - BOILER SLAG

Bulk Materials International Company Inc.

silicon dioxide SiO_2	43.2%
aluminum oxide Al_2O_3	18.5%
iron oxide Fe_2O_3	27%
magnesium oxide MgO	2%
calcium oxide CaO	7%
sulfur trioxide SO_3	3%

DHRS # 82315

Southeastern Environmental Laboratories, Inc.
80 Industrial Loop North, Building 5
Orange Park, FL 32073
(904) 269-6176

DHRS E-82179

CQAP # 880633G

Conrad Yelvington
460 Bay Point Way N.
Jacksonville, Florida 32259

Sampled By:	Client
Client Job/PO No.:	H/S - [illegible]
Project Name:	Sandblasting Abrasive
Submission Number:	9900160
Reported Date:	11/17/99

Description **Sample ID**

Sandblasting Abrasive

Sample Date: 11/10/99

Parameter	**Result**	**Units**	**Method**	**Analyst Initials**	**Date/Time**
Arsenic	U 0.25	mg/l	1311/6010	VP	11/17/99
Barium	0.13	mg/l	1311/6010	VP	11/17/99
Cadmium	U 0.10	mg/l	1311/6010	VP	11/17/99
Chromium	U 0.10	mg/l	1311/6010	VP	11/17/99
Lead	U 0.10	mg/l	1311/6010	VP	11/17/99
Mercury	U 0.005	mg/l	1311/7471	VP	11/17/99
Selenium	U 0.25	mg/l	1311/6010	VP	11/17/99
Silver	U 0.20	mg/l	1311/272.1	VP	11/17/99

5 Day Turn Around

Approved By: Bradford Murphy

STATE OF FLORIDA DEPARTMENT OF TRANSPORTATION
AGGREGATE SYSTEM
FINE AGGREGATE CODE FORM

SOURCE IDENTIFICATION

PROJECT NO. ______ PAY ITEM NO. ______ MATERIAL NO. ______

SAMPLE NO. 2 LAB NO. 2 TESTED BY PDPG DATE SAMPLED 02/22/01

SAMPLED BY FRANK M. IATE TESTED 02/23/01 SOURCE NO. (MINE/TERMINAL) ______ MINE NO. ______

MATERIAL IDENTIFICATION

MATERIAL CODE ______ MATERIAL TYPE ______ SAMPLE TYPE ______ SAMPLED FROM ______

PROCESS ______

NFORMATION ______

TEST RESULTS

FM ______ TARGET FM ______ PASS 200 9.26 APPARENT ______

______ TYPE GV ______ MOISTURE CONTENT 0.3% ABSORP. ______

% CARB ______ MOD L.A. ______ SPGR(DRYBULK) ______ MOD GRAD ______

BULK(SSD) ______ DES MIX ______

ASPHALT / CONCRETE PLANT NO. ______

REMARKS NFCT MATERIAL

SAMPLE WT. 444.8 gms/lbs -DRY WT. 417.4 = loss 27.4 + PAN WT. 13.8

WEIGHT (WT.)

%-200=[(Origional Dry Wt. -Dry Wt. After Washing)+Minus 200 Mateial From Dry Sieving] x 100/origional Dry Wt.

Gradation 444.8

[illegible]	SIEVE SIZE	ACCUM WT.	% WEIGHT	% RETAINED	% PASSING	REMARKS
1	3/8"-9.5mm	0.0	0.0%	0.0%	100.0%	
2	No.4-4.75mm	2.5	0.6%	0.6%	99.4%	
3	No.10-2.00mm	4.7	1.1%	1.1%	98.9%	
4	N0.40-425um	199.6	44.9%	44.9%	55.1%	
5	N0.80-180um	327.0	73.5%	73.5%	26.5%	
6	NO.100-150M	351.6	79.0%	79.0%	21.0%	
7	NO.200-75MM	401.80	90.3%	90.3%	9.7%	
TOTAL WEIGHT		415.60				

9

**Southeastern Environmental
Laboratories, Inc.
80 Industrial Loop North, Building 5
Orange Park, FL 32073
(904) 269-6176**

DHRS E-82179

CQAP # 880633G

Conrad Yelvington
460 Bay Point Way N.
Jacksonville, Florida 32259

Sampled By: Client
Client Job/PO No.:
Project Name: NFCT
Submission Number: 10006422
Reported Date: 2/23/01

Description **Sample ID**

Gross

Sample Date: 2/21/01

Parameter	**Result**	**Units**	**Method**	**Date/Time**
Arsenic	U 0.100	mg/kg	6010	2/22/01
Barium	796	mg/kg	6010	2/22/01
Cadmium	U 0.030	mg/kg	6010	2/22/01
Chromium	115	mg/kg	6010	2/22/01
Copper	599	mg/kg	6010	2/22/01
Iron	256	mg/l	6010	2/23/01
Lead	16.3	mg/kg	6010	2/22/01
Mercury	0.091	mg/kg	7470	2/23/01
Nickel	33.5	mg/kg	6010	2/22/01
Selenium	U 0.200	mg/kg	6010	2/22/01
Silver	U 0.030	mg/kg	6010	2/22/01
Zinc	112	mg/kg	6010	2/22/01

**Southeastern Environmental
Laboratories, Inc.
80 Industrial Loop North, Building 5
Orange Park, FL 32073
(904) 269-6176**

DHRS E-82179

CQAP # 880633G

Conrad Yelvington
460 Bay Point Way N.
Jacksonville, Florida 32259

Post-it® Fax Note 7671	Date 2-26	# of pages ▶ 3
To Frank Milton	From Wanda	
Co./Dept.	Co.	
Phone #	Phone #	
Fax #	Fax #	

Sampled By: Client
Client Job/PO No.:
Project Name: NFCT
Submission Number: 10006422
Reported Date: 2/23/01

Description	Sample ID
Fines (-200)	

Sample Date: 2/21/01

Parameter	Result	Units	Method	Date/Time
Arsenic	U 0.100	mg/kg	6010	2/22/01
Barium	696	mg/kg	6010	2/22/01
Cadmium	U 0.030	mg/kg	6010	2/22/01
Chromium	124	mg/kg	6010	2/22/01
Copper	793	mg/kg	6010	2/22/01
Iron	268	mg/l	6010	2/23/01
Lead	229	mg/kg	6010	2/22/01
Mercury	0.634	mg/kg	7470	2/23/01
Nickel	35.9	mg/kg	6010	2/22/01
Selenium	U 0.200	mg/kg	6010	2/22/01
Silver	U 0.030	mg/kg	6010	2/22/01
Zinc	126	mg/kg	6010	2/22/01

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**Southeastern Environmental
Laboratories, Inc.
80 Industrial Loop North, Building 5
Orange Park, FL 32073
(904) 269-6176**

DHRS E-82179

CQAP # 880633G

Conrad Yelvington
460 Bay Point Way N.
Jacksonville, Florida 32259

Sampled By: Client
Client Job/PO No.:
Project Name: NFCT
Submission Number: 10006422
Reported Date: 2/23/01

Description **Sample ID**

SPLP

Sample Date: 2/21/01

Parameter	Result	Units	Method	Date/Time
Arsenic	U 0.100	mg/l	1312/6010	2/22/01
Barium	0.420	mg/l	1312/6010	2/22/01
Cadmium	U 0.030	mg/l	1312/6010	2/22/01
Chromium	U 0.050	mg/l	1312/6010	2/22/01
Lead	U 0.100	mg/l	1312/6010	2/22/01
Mercury	U 0.005	mg/l	1312/7470	2/23/01
Selenium	U 0.200	mg/l	1312/6010	2/22/01
Silver	U 0.030	mg/l	1312/6010	2/22/01
Copper	3.27	mg/l	1312/6010	2/22/01
Iron	5.76	mg/l	1312/6010	2/23/01
Nickel	0.027	mg/l	1312/6010	2/22/01
Zinc	7.28	mg/l	1312/6010	2/22/01

Approved By: Radford Murphy

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RINKER Environmental Services, INC.

COMPQAP #950491
HRS #E86536

Materials Analysis Report

REPORT DATE	2/19/98
SAMPLE DATE	2/4/98
SAMPLE SOURCE	[redacted]
REFERENCE	46
R.E.S. ID NUMBER	8920
SAMPLE TYPE	Black Sand

PARAMETER	RESULT	UNITS	METHOD	D. LIMITS	ANALYSIS DATE	ANAL INITIAL
Arsenic	0.6	mg/kg	7060	0.5	2/9/98	PEP
Barium	379	mg/kg	7080	0.9	2/10/98	PEP
Cadmium	0.05	mg/kg	7131	0.02	2/6/98	PEP
Chromium	35.4	mg/kg	7191	0.8	2/10/98	PEP
Mercury	BDL	mg/kg	7471A	1.0	2/5/98	PEP
Lead	7.0	mg/kg	7420	0.1	2/11/98	PEP
Selenium	0.5	mg/kg	7740	0.4	2/9/98	PEP
Silver	BDL	mg/kg	7761	0.1	2/6/98	PEP
Copper	14.5	mg/kg	7210	1.0	2/11/98	JSP
Zinc	43.0	mg/kg	7950	1.0	2/11/98	JSP

Juan A. Gonzalez

Juan Gonzalez
QA/QC Manager

RINKER Environmental Services, INC.

COMPQAP #950491
HRS #E86536

Materials Analysis Report

REPORT DATE	2/19/98
SAMPLE DATE	2/4/98
SAMPLE SOURCE	[redacted]
REFERENCE	48
R.E.S. ID NUMBER	8921
SAMPLE TYPE	Black Sand

PARAMETER	RESULT	UNITS	METHOD	D. LIMITS	ANALYSIS DATE	ANAL INITIAL
Arsenic	1.1	mg/kg	7060	0.5	2/9/98	PEP
Barium	580	mg/kg	7080	0.9	2/10/98	PEP
Cadmium	0.12	mg/kg	7131	0.02	2/6/98	PEP
Chromium	49.7	mg/kg	7191	0.8	2/10/98	PEP
Mercury	BDL	mg/kg	7471A	1.0	2/5/98	PEP
Lead	29.5	mg/kg	7420	0.1	2/11/98	PEP
Selenium	BDL	mg/kg	7740	0.4	2/9/98	PEP
Silver	BDL	mg/kg	7761	0.1	2/6/98	PEP
Copper	2850	mg/kg	7210	1.0	2/11/98	JSP
Zinc	865	mg/kg	7950	1.0	2/11/98	JSP

Juan Gonzalez
QA/QC Manager

RINKER Environmental Services, INC.

COMPQAP #950491
HRS #E86536

Materials Analysis Report

REPORT DATE	2/19/98
SAMPLE DATE	2/4/98
SAMPLE SOURCE	[redacted]
REFERENCE	48
R.E.S. ID NUMBER	8922
SAMPLE TYPE	Black Sand

PARAMETER	RESULT	UNITS	METHOD	D. LIMITS	ANALYSIS DATE	ANAL. INITIAL
Arsenic	1.3	mg/kg	7060	0.5	2/9/98	PEP
Barium	170	mg/kg	7080	0.9	2/10/98	PEP
Cadmium	0.03	mg/kg	7131	0.02	2/6/98	PEP
Chromium	32.8	mg/kg	7191	0.8	2/10/98	PEP
Mercury	BDL	mg/kg	7471A	1.0	2/5/98	PEP
Lead	7.5	mg/kg	7420	0.1	2/11/98	PEP
Selenium	BDL	mg/kg	7740	0.4	2/9/98	PEP
Silver	BDL	mg/kg	7761	0.1	2/6/98	PEP
Copper	39.1	mg/kg	7210	1.0	2/11/98	JSP
Zinc	76.5	mg/kg	7950	1.0	2/11/98	JSP

Juan Gonzalez
QA/QC Manager

RINKER Environmental Services, INC.

COMPQAP #950491
HRS #E86536

Materials Analysis Report

REPORT DATE	2/19/98
SAMPLE DATE	2/4/98
SAMPLE SOURCE	[redacted]
REFERENCE	79
R.E.S. ID NUMBER	8923
SAMPLE TYPE	Black Sand

PARAMETER	RESULT	UNITS	METHOD	D. LIMITS	ANALYSIS DATE	ANAL INITIAL
Arsenic	BDL	mg/kg	7060	0.5	2/9/98	PEP
Barium	1030	mg/kg	7080	0.9	2/10/98	PEP
Cadmium	0.06	mg/kg	7131	0.02	2/6/98	PEP
Chromium	49.2	mg/kg	7191	0.8	2/10/98	PEP
Mercury	BDL	mg/kg	7471A	1.0	2/5/98	PEP
Lead	13.0	mg/kg	7420	0.1	2/11/98	PEP
Selenium	BDL	mg/kg	7740	0.4	2/9/98	PEP
Silver	BDL	mg/kg	7761	0.1	2/6/98	PEP
Copper	45.0	mg/kg	7210	1.0	2/11/98	JSP
Zinc	21.2	mg/kg	7950	1.0	2/11/98	JSP

Juan A. Gonzalez

Juan Gonzalez
QA/QC Manager

RINKER Environmental Services, INC.

COMPQAP #950491
HRS #E86536

Materials Analysis Report

REPORT DATE	2/19/98
SAMPLE DATE	2/4/98
SAMPLE SOURCE	[redacted]
REFERENCE	38
R.E.S. ID NUMBER	8924
SAMPLE TYPE	Black Sand

PARAMETER	RESULT	UNITS	METHOD	D. LIMITS	ANALYSIS DATE	ANAL. INITIAL
Arsenic	BDL	mg/kg	7060	0.5	2/9/98	PEP
Barium	215	mg/kg	7080	0.9	2/10/98	PEP
Cadmium	0.02	mg/kg	7131	0.02	2/6/98	PEP
Chromium	24.0	mg/kg	7191	0.8	2/10/98	PEP
Mercury	BDL	mg/kg	7471A	1.0	2/5/98	PEP
Lead	6.0	mg/kg	7420	0.1	2/11/98	PEP
Selenium	BDL	mg/kg	7740	0.4	2/9/98	PEP
Silver	BDL	mg/kg	7761	0.1	2/6/98	PEP
Copper	68.0	mg/kg	7210	1.0	2/11/98	JSP
Zinc	18.8	mg/kg	7950	1.0	2/11/98	JSP

Juan A. Gonzalez

Juan Gonzalez
QA/QC Manager

Advanced Environmental Laboratories, Inc.

Aanlytical Report

Client: Gulf Marine Repair.
Project No.: 32937
Matrix: TCLP Extract

Report No.: J001042
Date Sampled: Unknown
Date Submitted: 5/9/00
Date Reported: 5/11/00
Page No.: 2 of 2

[redacted]
Units: mg/L

				Lab Code:	J001042-1	J001108-1-mb
Aanlyte	**Method**	**MRL**	**TCLP Limits**	**Date Aanlyzed**	**Sand Blast**	**Method Blank**
Arsenic	6010B	0.050	5.0	5/10/00	U	U
Barium	6010B	0.25	100	5/10/00	**0.568**	U
Cadmium	6010B	0.025	1.0	5/10/00	U	U
Chromium	6010B	0.05	5.0	5/10/00	U	U
Lead	6010B	0.050	5.0	5/10/00	U	U
Selenium	6010B	0.05	1.0	5/10/00	U	U
Silver	6010B	0.05	5.0	5/10/00	U	U
Mercury	7470A	0.0020	0.20	5/10/00	U	U

GALE
EUSTACE

Not detected above the MRL
RL. Method Reporting Limit

SCHNEIDER LABORATORIES

INCORPORATED

2512 W. Cary Street • Richmond, Virginia • 23220-5117
804-353-6778 • 800-785-LABS (5227) • (FAX) 804-353-6928
Excellence in Service and Technology
AIHA 8936, ELLAP 8936, NVLAP 1150, NYELAP 11413, CAELAP 2078

LABORATORY ANALYSIS REPORT

EPA SW846 Method 1311 (Toxicity Characteristic Leachate Procedure)

ACCOUNT:	1669-99-23	**DATE COLLECTED:**	7/27/99
CLIENT:	Worth Contracting	**DATE RECEIVED:**	7/29/99
ADDRESS:	2112 Jernigan Rd Jacksonville, Fl. 32207	**DATE ANALYZED:**	8/2/99
		DATE REPORTED:	8/2/99
P.O.#:			
PROJECT NAME:	Washington Terrace	**SAMPLE TYPE:**	TCLP
PROJECT NO.:	230		
JOB LOCATION:	St. Pete, Fl.		
CLIENT SAMPLE NO.:	23010		
SLI SAMPLE NO.:	1990319		

METAL NAME:	ACTUAL CONC.	UNITS	ANALYSIS METHOD	REGULATORY LIMIT(ppm)
Arsenic (As)	<0.04	ppm	EPA 6010	5.0
Barium (Ba)	1.19	ppm	EPA 6010	100.0
Cadmium (Cd)	<0.02	ppm	EPA 6010	1.0
Chromium (Cr)	0.06	ppm	EPA 6010	5.0
Lead (Pb)	<0.20	ppm	EPA 7420	5.0
Mercury (Hg)	<0.005	ppm	EPA 7470	0.2
Selenium (Se)	<0.05	ppm	EPA 6010	1.0
Silver (Ag)	<0.02	ppm	EPA 6010	5.0

SAMPLE TYPE: Blast Waste
SAMPLE pH: 8.35
ANALYST: CAROLYN C. RING

REVIEWED BY Matthew D. [illegible], Analyst

*Quality Control Data available upon request. *For true values, assume 2 significant figures. Sample concentrations below the Minimum Reporting Limit are indicated with a "less than (<)" sign. Note on measurement units: mg/L = ppm (parts per million). All testing is done in strict accordance with Schneider Laboratories, Inc. protocol.*

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Screen or mesh size

In the language of the sandblaster the size of the blasting grit is referred to as the mesh or screen size. The screen number is the number of equal size holes in a 1" square screen. The larger the number, the more holes and therefore the smaller each hole is. The lower the number the coarser the media. Please note that the screen material takes up space so a #4, which has 4 holes per square inch is not 1/4" in size. It is actually about 3/16" or 1/16" less then 1/4".

The size of a particle of blasting grit is the number given to the smallest screen it will pass through. In other words if something passes through a #30 screen but stops at the #25 screen it is known as a #30.

In blasting you want to have a mix of sizes to give the best cleaning and profile so you normally see sizes like 20/40. This means that most of what is in the mix is a #30 with part of it finer, up to a #40 and some of it coarser, down to a #20.

The terms fine, medium or coarse or the numbers 0, 00, 000 or 2, 3 or 4 given out by some manufacturers are not what you want to use to compare sizes between two companies. One companies fine can be someone else's medium.

For your information:

- Regular ground coffee is approximately a 16/40 mesh.
- Sugar is about a 50/80 mesh.
- Table salt around a 30/80 mesh.
- Fine ground black pepper is a 30/50 mesh.

The following is a friendly comparison chart of National Bureau of Standards (NBS) screen sizes used in the blasting industry

Screen Number	**Size in MM**	**Size in Inches**	**Nearest Fraction***
4	4.75	.187	3/16"
5	4.00	.157	5/32"
6	3.35	.132	1/8"
7	2.80	.111	
8	2.36	.0937	3/32"
10	2.00	.0787	5/64"
12	1.70	.0661	
14	1.40	.0555	
16	1.18	.0469	3/64"
18	1	.0394	

20	.85	.0331	
25	.71	.0278	1/32"
30	.60	.0234	
35	.50	.0197	
40	.425	.0165	
45	.355	.0139	1/64"
50	.300	.0117	
80	.180	.0070	
100	.150	.0053	
120	.125	.0049	
200	.075	.0029	
325	.045	.0017	

*Close to, but not exact in every case!

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Got a question - sales@sandblaster.com is the address for answers.

Revised: October 05, 2000.

Examples of cleaning rates of some common abrasives:

Abrasive	Consumption	Production Rate	Comments
Silica Sand 16/40 mesh	2.6 lbs/sq/ft	4.75 sq/ft/min	1.5 mil profile Dusty
Coal Slag 12/40 mesh	3.2 lbs/sq/ft	3.83 sq/ft/min	2.5 - 3 mil profile Medium dust and embeddment
Steel Grit #40	5.5 lbs/sq/ft	3.06 sq/ft/min	2.5 mil profile No dust, but high embeddment
Garnet #36	3.6 lbs/sq/ft	3.55 sq/ft/min	1.5 mil profile Medium dust and embeddment
Aluminum Oxide #36	3.1 lbs/sq/ft	4.58 sq/ft/min	1.5 mil profile Very little dust
Staurolite 50/100 mesh	3.1 lbs/sq/ft	4.85 sq/ft/min	.5 mil profile medium dust
Copper Slag 16/40 mesh	3.1 lbs/sq/ft	4.36 sq/ft/min	2 mil profile Medium dust and embeddment
Brown Blast 16/50 mesh	1.5 lbs/sq/ft	3.0 sq/ft/min	3 mil profile Medium dust and embeddment
Glass Grit 8/40 mesh	2.8 lbs/sq/ft	3.33 sq/ft/min	4 mil profile Medium dust and embeddment
Crystalgrit 20/70 mesh	1.5 lbs/sq/ft	5.97 sq/ft/min	3 - 4 mil profile Very low dust and embeddment

The above numbers were derived from tests by Virginia Materials and others including SSPC. All testing was done with a #6 (3/8") nozzle at 100 PSI and blasting to a SSPC 10 (near white finish) on new steel with mil scale only.

Many, many, many factors contribute to the consumption and production rates of abrasive blasting and your results may be very different from the above. This is only for comparison purposes to show the **typical differences** between materials.

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Revised: October 05, 2000.

Beneficial Reuse Program

Handling spent abrasives with common sense and the environment in mind!

It has come to our attention in recent years that disposing of the spent abrasive is frequently almost as costly as actually buying the grit. In order to help customers with this problem, Virginia Materials has come up with a solution that not only helps our customers but also helps to preserve the environment.

Instead of disposing of the spent grit in landfills, as is customary, Virginia Materials accepts spent grit from our customers. After collecting and screening the grit to ensure the removal of all oversize trash we ship it to a portland cement manufacturer as a feed stock. The cement company superheats this raw material to a molten state (2600° F) along with other materials and uses it to make clinker, which is then ground up and used to produce portland cement. Thus, our customers no longer need to take up precious landfill space with tons of waste grit which can be better used to make a useful end product, which will probably itself be recycled, as concrete is almost infinitely recyclable these days. This also reduces the use of our natural resources by cutting into the use of precious minerals that would have been used.

Another benefit of this beneficial reuse plan is that the waste grit is safely disposed of in a manner whereby it will never become a problem and be traced back to the generator, as can happen with land filling. Such as could be the case in a "Superfund Site" with liability to everyone who disposed of something in it - hazardous or not! This plan is heartily endorsed by the Department of Environmental Quality Waste Division authorities and by all customers who have taken advantage of it. Virginia Materials is fully licensed by the State of Virginia as a material recovery facility.

To view our full program download this Adobe Acrobat file - Beneficial Reuse Program

Home | Information | What's New | Products

Virginia Materials
3306 Peterson Street, Norfolk, VA 23509-2415
Phone: 757-855-0155, FAX: 757-857-5631

Beneficial Reuse and Disposal of Spent Abrasives Program

Tomorrow's Future Starts Today!

22 Pamphlet

TABLE OF CONTENTS

Background

Virginia Material's program for the removal of spent abrasives has been developed to meet the increased need to recycle waste products rather than dumping those materials in landfills. The use of spent abrasives in the portland cement manufacturing process converts a waste material into a useful product, thus removing the potential risk that landfilled abrasive wastes may have should they become a future problem. By using your spent abrasive as a raw material in a new product it "*Breaks the chain of custody*!"

On October 28, 1997; Virginia Materials was issued the first and so far the only permit for a Materials Recovery Facility in the Commonwealth of Virginia which serves as a spent blast grit reprocessing facility at its location - 3306 Peterson Street, Norfolk, Virginia. To date more the 150,000 tons have been recycled which otherwise would have been destined to be placed into landfills. Of course at the same time this eliminates depletion of our natural resources and minerals that would have been used otherwise.

Working with the Department of Environmental Quality and our cement industry consultant, Bulk Materials we have developed standards to enable us to meet the relevant regulatory requirements as well as kiln requirements by sampling: testing and classifying spent abrasive blasting materials. Materials meeting the criteria for acceptance by us are now processed and transported by rail to cement plants. In general, the only spent abrasives that will be unacceptable for shipping will be those containing more than 5 parts per million (PPM) of lead when tested by the TCLP leachate extraction procedure or otherwise considered hazardous.

The procedures and fee for removal and disposal will depend on the volume and location of the spent abrasive. Our customer's responsibility will be to provide assistance with sampling and testing of the waste material prior to moving and classification then to provide facilities and labor for loading of accepted material into dump trailers, or trucks, dumpsters, rail cars, barges, or VM bins prior to shipment to Norfolk.

Virginia Materials offers this spent abrasive disposal service to provide a cost-effective method of reprocessing a waste material to provide a new, useful product and reduce the amount of material being placed in landfills. Please contact Ben Burns at VM if we can be of assistance to you with this program.

Your Responsibilities

The Commonwealth of Virginia Department of Environmental Quality Division of Waste Operations Guidance Document No. 97-2001 sets the standard for the handling, storage and disposal of spent sandblasting abrasives for the Commonwealth of Virginia. Other states will have similar rules and regulations and should be read and understood by those concerned.

The items of most importance to the facility where the sandblasting is taking place are contained in section III and section IV and paraphrased here:

> ***From Section III***
>
> *"Appropriate Container" as pertains to spent and/or discarded sandblast grit falls into two categories; long term (i.e., longer than 90 days) and short term (i.e., less than or equal to 90 days):*
>
> - *for long term storage, means an enclosed building, tank, or impermeable pad with curbs and drains. Containers which are not covered must be capable of collecting and controlling, in addition to the material contained, the water volume resulting from a 24-hour, 25 year storm event. Also, containers for long term storage must have outlets or drains for proper removal of collected liquids to a sanitary sewer or holding tank for ultimate disposal at an approved publicly-owned treatment works (POTW) or other permitted wastewater treatment facility;,*
> - *for short term storage, means dumpsters or roll off containers which are covered with a tarp, or an enclosed building, or if material is piled on the ground (i.e., a waste pile), a berm around such pile, with the pile covered with a tarp. These containers must be designed to minimize run-on and run-off.*
>
> ***From Section IV***
>
> 1. *Spent sandblast grit from sandblasting operations that is being generated on a site shall be stored or in appropriate containers for no more than 90 days. No spent sandblast grit may be brought from off-site. Best management practices for the sandblasting operations shall be implemented so that the spent sandblast material is not discharged to state waters.*

As you can see from the above it is required that the sandblasting facility to remove all spent abrasives with in the defined "short term" period of 90 days.

Don't take a chance, Virginia Materials has the necessary facilities for storage and processing of your spent abrasives.

How it Works

CHANGING WASTE INTO A USEFUL PRODUCT

All of the spent sandblast abrasives accepted by our licensed Material Recovery Facility at Virginia Materials are presently processed and transported to a cement kiln manufacturer. There they are used as a raw material "feed stock" and are mixed with other raw materials to produce Portland Cement. This mix of materials is processed and burned in a kiln with a 3,400°F temperature achieving a material temperature of 2,800°F. The spent sandblast abrasives are chemically changed and recycled to create a "risk-free" environmentally safe product called a clinker which is cooled and ground into portland cement.

LEAD BASED COATING REMOVAL

Are you faced with removing lead-based paints? Blastox has become the recognized leader for the removal of lead based and other heavy metals paints. When properly utilized, sandblasting abrasives pre-blended with Blastox will not mask hazardous lead waste. A potentially lead contaminated hazardous waste will become non-hazardous waste and can be placed in our Beneficial Reuse Program.

Virginia Materials is an authorized blender of Blastox and will accept the used material into our Beneficial Reuse Program.

PROGRAM MANAGER

Mr. Benjamin Burns has been appointed our "Beneficial Reuse Program" Manager. Ben has been coordinating Virginia Materials efforts and oversees the program since its inception. Ben is a graduate of Old Dominion University with a strong work ethic and gets the job done right the first time.

Ben Burns along with all the Virginia Materials staff is ready to help you with "Beneficial Reuse" including transportation, TCLP procedures, and with any other questions or concerns that may arise. Call Ben anytime!

Beneficial Reuse Participants

We are proud to highlight a few of our fine customers who have taken the initiative on their own to start recycling voluntarily. Thus helping themselves and the environment.

Alco Welding
Bay Mechanical
Consolidated Launcher
Holmes Brothers
Lockly Mfg.
Metro Machine
Moon Engineering
Norshipco
Reliable Trash
Superior Disposal
Vanwin Coatings

Ampro
Colonnas Shipyard
Hico
Huntsman Chemical
Marine Hydraulics
Mid Atlantic Coatings
Norfolk Naval Shipyard
Oilfield Pipe & Supply
Riggins
Technico
Virginia Machine
North Carolina DOT

Service Fees

Our charge to you for processing and transportation to the portland cement manufacturer is $23.90/Ton FOB Virginia Materials.

In certain situations, based upon large volume, it is possible to develop a reduced service fee. Upon your request we will be happy to design a program to meet you specific goals.

Please note that we must have a TCLP report on the material to assure that it is non-hazardous before shipment and handling.

Transportation

There are a number of ways for you to get the spent abrasive material to us that we can arrange for you. The least expensive is generally via dump trailer or truck; however, roll off containers may be used.

We also offer customers who use our steel bins to take delivery of new abrasive the option to return the spent material in the same bins, at no additional cost then what you would normally pay for return of the empty bins.

The use of bulk bags or super sacks is another permissible method to return spent abrasives back to us. This can work well when the new abrasives are purchased in the super sacks and you, the user refill it for transportation via truck, rail or boat if tonnages warrant it.

For large volume disposal needs in excess of 80 tons and it the distance is considerable, Virginia Materials may be able to arrange for the use of open top hopper rail cars.

RESPONSE TO COMMENTS DOCUMENT

Land Disposal Restrictions--Phase IV: Final Rule Promulgating Treatment Standards for Metal Wastes and Mineral Processing Wastes; Mineral Processing Secondary Materials and Bevill Exclusion Issues; Treatment Standards for Hazardous Soils; and Exclusion of Recycled Wood Preserving Wastewaters

Volume 1
Phase III Proposed Rule Comments
March 2, 1995

U.S. Environmental Protection Agency
Office of Solid Waste
401 M Street, S.W.
Washington, D.C. 20460

April 30, 1998

List of Phase IV Land Disposal Restriction Codes, Description, and Location by Page Number

Code	Description	Page Number
FOUN1	Comments on Foundry Sand Issues	1

Index of Commenters and Location of Comment, By Issue

Phase III LDR Rule: Comments and Responses or Issues Related to Foundry Wastes

---

Issue: FOUN1-004 Respondent: TTS

Dcn: PH3P004 Extension: CBI: N
Commenter: TANOAK ENTERPRISES, INC

Comment Number: 00001

//COMM1
//RESPTTS
//SUBJFOUN1-004

THE FEDERAL REGISTER STATES ON PAGE 11731:

'THE AGENCY IS AWARE OF A PRACTICE WITHIN THE FOUNDRY INDUSTRY THAT RECYCLES FOUNDRY SAND BY THERMALLY OXIDIZING IMPURITIES. IT IS EPA'S VIEW THAT THIS PROCESS WOULD VIOLATE THE POLICY AGAINST COMBUSTION OF INORGANICS, ...'.

IT IS RECOGNIZED THAT THE AGENCY'S CONCERN IS DIRECTED TOWARDS AN UNCONTROLLED (AND IMPERMISSIBLE) RELEASE OF LEAD INTO THE ENVIRONMENT. THE AGENCY ALSO RAISES CONCERN WITH RESPECT TO THE TREATMENT OF LEAD CONTAINING SAND BY ADDITION OF IRON DUST AND FINALLY REQUESTS ON PAGE 11732:

'COMMENTS AND DATA ARE ALSO SOLICITED ON WHETHER A TEST METHOD OTHER THAN THE TCLP IS MORE APPROPRIATE FOR MEASURING COMPLIANCE OF THIS WASTE.'

THIS COMMENT ADDRESSES SPECIFICALLY THE SITUATION OF FOUNDRY SAND FROM BRASS AND BRONZE FOUNDRIES WHICH SHOWS TOXICITY CHARACTERISTICS FOR LEAD. IT OFFERS THE FOLLOWING CONSIDERATIONS:

1 TREATMENT OF SAND IN 'HIGH TEMPERATURE' THERMAL DEVICES
2 TREATMENT OF SAND IN AN ALTERNATIVE METHOD, USING 'LOW

TEMPERATURE' 3 CONSIDERATION OF AN ALTERNATE TESTING METHOD

1 TREATMENT OF SAND IN 'HIGH TEMPERATURE' THERMAL DEVICES

THIS AGENCY'S PROPOSAL STATS ON PAGE 11731:

'IS EPA'S VIEW THAT THIS PROCESS WOULD VIOLATE THE POLICY AGAINST COMBUSTION OF INORGANICS, ...'.

MUCH OF THE WORK CARRIED ON WITH RESPECT TO 'HIGH TEMPERATURE PROCESSING' IS BASED ON US PATENT 4408985 OF OCT. 11, 1983 WHERE LEAD BEARING FOUNDRY SAND WAS THERMALLY PROCESSED AND WHERE THE FOLLOWING CLAIMS ARE MADE:

'(2) THE METHOD OF CLAIM 1, AND FURTHER WHEREIN THE ROASTING IS CARRIED OUT IN AN OXYGEN ATMOSPHERE'
'(4) THE METHOD OF CLAIM 3, AND FURTHER WHEREIN THE ROASTING IS CONDUCTED AT A TEMPERATURE OF AT LEAST 710°C'
'(5) THE METHOD OF CLAIM 4, AND FURTHER WHEREIN THE ROASTING IS CONDUCTED AT A TEMPERATURE OF APPROXIMATELY 800°C FOR A PERIOD OF APPROXIMATELY 45 MINUTES' '(7) A SAND COMPOSITION HAVING LEAD COMPOUNDS THEREIN, THE TOTAL LEAD COMPOUNDS BEING PRESENT IN EXCESS OF 5 PPM BUT THE ACETIC ACID SOLUBLE LEAD COMPOUNDS BEING PRESENT IN NO GREATER THAN 5 PPM'.

WHILE THIS PATENT REQUIRES AN OXIDIZING ATMOSPHERE AND PRESCRIBES A MINIMUM TEMPERATURE OF 710°C, IT DOES NOT PROVIDE A MATERIAL BALANCE WHICH LEAVES THE POSSIBILITY OF LEAD EMISSIONS VIA THE EXHAUST GAS STREAM.

"LANGE'S HANDBOOK OF CHEMISTRY", 14TH EDITION [MCGRAW-HILL] PROVIDES ON PAGES 3.36 AND 3.37 BOILING POINTS FOR CERTAIN LEAD OXIDES OF 595°C AND ALSO SUGGESTS THAT SUCH OXIDES WOULD DISSOCIATE. SINCE THE PREVIOUSLY SUGGESTED MINIMUM TEMPERATURE, COMBINED WITH THE REQUIREMENT FOR AN OXIDIZING ATMOSPHERE, IS SUBSTANTIALLY ABOVE THE BOILING POINT FOR THOSE LEAD OXIDES, THIS WOULD SUGGEST STRONG POSSIBILITY FOR THE GENERATION OF A LEAD COMPOUND VAPOR PHASE.

RESEARCH PUBLISHED IN SEPTEMBER 1992 ['DEVELOPMENT OF A STEEL-FOUNDRY WASTE SAND RECLAMATION PROCESS', MICHIGAN TECHNOLOGICAL UNIVERSITY, INSTITUTE OF MATERIALS PROCESSING], REPORTS ABOUT LEAD ACCUMULATION ON THE SAND FROM A LEAD CONTAINING BINDER IN MULTI-CYCLE PROCESSING. HOWEVER, THE CONDITIONS IN THIS CASE WERE

DIFFERENT FROM THOSE REQUESTED IN THE BEFORE MENTIONED PATENT, NAMELY

* THERMAL RECLAMATION WAS IN THE LABORATORY IN A LINDBERG BOX FURNACE (PAGE 61 OF REPORT). NO INFORMATION IS PROVIDED WITH RESPECT TO THE PROCESSING ATMOSPHERE OR EXHAUST GAS FLOW RATES.
* ALL CYCLING TESTS WERE PERFORMED AT A RECLAMATION TEMPERATURE OF 600°C (PAGE 69 OF REPORT)
* LEACHATE VALUES IN THE RECLAIMED SAND AS HIGH AS 700 PPM WERE DETERMINED (TABLE 80 OF REPORT). HOWEVER, IT MUST ALSO BE STATED THAT THE PB LEACHATE VALUES FROM PROCESSING A LEAD FREE BINDER WERE DETERMINED TO BE AS HIGH AS 39 PPM!

IF WE DISREGARD THE INCONSISTENCY JUST STATED, IT IS QUITE POSSIBLE THAT AN ACCUMULATION OF LEAD WAS OBSERVED, KEEPING IN MIND THE UNCERTAINTY WITH RESPECT TO THE EXISTING FURNACE ATMOSPHERE AS WELL AS THE FACT THAT THE PROCESSING TEMPERATURE WAS VERY CLOSE TO (AND POSSIBLY BELOW) THE BOILING TEMPERATURE OF THE LOWEST BOILING LEAD OXIDES.

IF WE ASSUME THAT THE GENERALLY APPLIED THERMAL PROCESSING CONDITIONS WOULD BE AMENABLE TO VAPOR GENERATION, WE MUST NOW CONSIDER WHAT THE CONSEQUENCES OF SUCH VAPOR GENERATION MIGHT BE.

FIRST, THERMAL 'RECLAIMERS' ARE SUBJECT TO THE EMISSION LIMITATIONS SPECIFIED BY THE CLEAN AIR ACT 1990 (CAA 1990). TITLE III DOES LIST 'LEAD COMPOUNDS'. THUS, ANY VAPORS WHICH MAY BE GENERATED BY THE HIGH TEMPERATURE PROCESSING MUST BE CONTROLLED AND CANNOT BE LEGALLY RELEASED TO THE ENVIRONMENT.

LEAD EMISSIONS FROM THERMAL PROCESSES ARE NOTHING NEW AND WE FIND FOR EXAMPLE IN "STANDARD HANDBOOK OF HAZARDOUS WASTE TREATMENT AND DISPOSAL" [MCGRAW-HILL] ON PAGE 8.63 THE FOLLOWING STATEMENTS:

'AT CEMENT-KILN TEMPERATURES, MATERIALS WHICH ARE ORDINARILY CONSIDERED NONVOLATILE NOT ONLY MELT, BUT BOIL'.

BUT THIS SAME ARTICLE WHICH REPORTS ABOUT THE COMBUSTION OF LEAD CONTAINING MATERIALS IN A CEMENT KILN THEN CONTINUES TO EXPLAIN:

'EXHAUST GASES EXITING THE KILN STACK ARE TYPICALLY AT TEMPERATURES BETWEEN 150°C (300°F) AND 250°C (480°F). CONSEQUENTLY, POTASSIUM

CHLORIDE, LEAD OXIDE, OR OTHER MATERIALS VOLATILIZED IN THE BURNING ZONE WILL CONDENSE ONTO PARTICLE SURFACES RATHER THAN BEING EMITTED WITH THE STACK GASES'.

THIS SITUATION IS COMPARABLE TO THE SITUATION IN 'THERMAL RECLAIMERS' IN THE FOUNDRY INDUSTRY AND SUGGESTS THAT, EVEN IF LEAD COMPOUND VAPORS WOULD BE EMITTED FROM THE HIGH TEMPERATURE ZONE, SUCH LEAD COMPOUNDS WOULD NOT BE RELEASED TO THE ENVIRONMENT AS VAPORS BUT WILL LIKELY CONDENSE ONTO OTHER PARTICULATE SURFACES (OR MAY CONDENSE INTO LEAD OXIDE PARTICLES). HOWEVER, THE CAA 1990 CLEARLY IMPOSES LIMITS WITH RESPECT TO MAXIMUM PERMISSIBLE LEAD COMPOUND EMISSIONS.

BEYOND THESE REGULATIONS, WE ALREADY HAVE THE REGULATION UNDER 40 CFR PART 60, SUBPART UUU WHICH APPLIES TO ALL 'CALCINERS' PROCESSING 'INDUSTRIAL SAND' (I.E. THERMAL RECLAIMERS AS USED IN FOUNDRIES). THIS REGULATION APPLIES TO ALL INSTALLATIONS AFTER APRIL 23, 1986. THE OPERATION OF A CONTINUOUS OPACITY MONITORING SYSTEM (COM) AS MANDATED UNDER THIS RULE WILL CONTROL THE EMISSION LIMITS FOR PARTICULATE MATTER - AND IT IS IN THIS FORM THAT THE LEAD WOULD BE EMITTED AFTER THE POLLUTION ABATEMENT SYSTEM IF NOT RETAINED BY SUCH SYSTEM. THUS, WE HAVE TWO PIECES OF LEGISLATION WHICH GOVERN AND CONTROL THE OPERATION OF THERMAL RECLAIMERS AND WE CAN THEREFORE ASSUME THAT UNCONTROLLED RELEASE OF LEAD IN ANY FORM TO THE ENVIRONMENT IS POSITIVELY AVOIDED (PREDICATED UPON COMPLIANCE WITH EXISTING LEGISLATION).

HOWEVER, THERE IS ALSO ANOTHER TECHNICALLY POSSIBLE FORM FOR 'LEAD CONTROL' WHICH IS PRODUCTION PROVEN AND WHICH SHALL BE DESCRIBED IN THE FOLLOWING CHAPTER 2.

2 TREATMENT OF SAND IN AN ALTERNATIVE METHOD, USING 'LOW TEMPERATURE'

THE DEVICE USED IN THIS PROCESS IS COVERED IN US PATENT 4,681,267 OF JULY 21, 1987 AND US PATENT 4,709,862 OF DECEMBER 1, 1987. IN CONTRAST TO THE AFOREMENTIONED 'HIGH TEMPERATURE' APPROACH, THIS SYSTEM USES THERMAL ENERGY ONLY TO ESSENTIALLY DRY THE FOUNDRY SAND AND EMBRITTLE ANY RESIDUAL BINDER SO THAT IT CAN BE PROPERLY REMOVED BY MEANS OF ATTRITION. THERMAL PROCESSING AND ATTRITION OCCUR SIMULTANEOUSLY IN THE SAME PROCESSING VESSEL. THE ATTRITION PRODUCT, WHICH NOW CONTAINS THE CONTAMINANT IN CONCENTRATED FORM IS COLLECTED IN AN APPROPRIATE DEVICE (CLOTH FILTER OR SIMILAR).

THE FACT THAT THE CONTAMINANT, FOR EXAMPLE LEAD, IS NOW CONCENTRATED IN A MUCH SMALLER VOLUME PERMITS TO CONSIDER METAL EXTRACTION FROM THIS PROCESS STREAM OR, IF STILL JUDGED UNECONOMICAL, PERMITS TO TREAT A MUCH SMALLER STREAM TO ACHIEVE COMPLIANCE WITH ENVIRONMENTAL REGULATIONS.

GIVEN THE FACT THAT ALREADY TODAY SUBSTANTIAL QUANTITIES OF PROCESS BY-PRODUCTS FROM BRASS AND BRONZE FOUNDRIES ARE BEING CHANNELED TOWARDS METAL RECOVERY SUCH AS GRINDINGS, TRIMMINGS, AND DROSS, MAKES METAL RECOVERY ALSO FROM THIS SMALL STREAM FROM SAND PROCESSING A REALISTIC POSSIBILITY.

PERFORMANCE OF 'LOW TEMPERATURE' SYSTEM (ENCL. A)

ENCL. A1 SHOWS HOW LEACHABLE LEAD CAN BE REDUCED IN SPENT SAND FROM A BRASS FOUNDRY FROM 24 PPM TO 3.1 PPM BY LEAD REMOVAL, USING COMBINED THERMAL (DRYING) PLUS ATTRITION AS PER US PATENTS 4,681,267 AND 4,709,862. LEAD REDUCTION TO EVEN LOWER RESIDUAL LEVELS IS POSSIBLY BY SIMPLE EXTENSION OF THE PROCESSING TIME. THE PROCESSING TEMPERATURE APPLIED IN DRYING IS CLEARLY BELOW THE BOILING POINT OF VARIOUS LEAD OXIDES. IT IS ALSO BELOW THEIR MELTING POINTS AND THE GENERATION OF LEAD COMPOUND VAPORS IS THEREFORE ELIMINATED. HOWEVER, WITH THE MUCH LOWER PROCESSING TEMPERATURES, THE POTENTIAL EMISSION OF HYDROCARBONS MUST BE CONSIDERED.

CONTRARY TO FLUID BEDS OR ROTARY KILNS, THIS PROCESS IS A BATCH PROCESS. A UNIT WITH CAPACITY 1 T/H IS SHOWN IN ENCL. A2. TESTING WAS PERFORMED BY MEASURING EXHAUST GAS TEMPERATURE AT POINT "A", I.E. IMMEDIATELY AT THE EXIT FROM THE PROCESS VESSEL AND WITHOUT ANY DILUTION. SAMPLES OF THE "PRODUCT OF COMBUSTION" [POC] WERE TAKEN AT POINT "B", THAT IS FROM THE EXHAUST GAS DUCT LEADING FROM THE PROCESSING VESSEL AND BEFORE THE GAS STREAM ENTERS EITHER CYCLONE OR CLOTH FILTER. THUS, THE TESTED STREAM REPRESENTS AN UNDILUTED POC SAMPLE.

THE GRAPH AS PER ENCL. A3 SHOWS THE TEMPERATURE RANGES FOR BOTH, SAND AND POC, FROM A TEST WHICH WAS PERFORMED OVER TEN (10) OPERATING HOURS, REPRESENTING 120 BATCHES.

THE POC TEMPERATURE IS LOW ENOUGH THAT NO FURTHER DILUTION IS REQUIRED PRIOR TO ENTERING A CLOTH FILTER. ENCL. A4 PROVIDES AN EVALUATION FROM THIS TEST AND DOCUMENTS THAT TOTAL EXHAUST GAS FLOW IN THIS SYSTEM IS ON THE ORDER OF 15 LBS PER MINUTE OR, BASED ON

THE PROCESSING CAPACITY OF 1 T/H, ON THE ORDER OF APPROX. 1,000 LBS/H POC FOR EACH TON OF SAND PROCESSED. THUS, THE POC TO SAND RATIO IS ON THE ORDER OF 0.5 VS. 5 (AND MORE) FOR FLUID BED OR ROTARY KILN SYSTEMS. THIS MEANS THAT POLLUTION ABATEMENT EQUIPMENT CAN BE HELD TO VERY SMALL SIZES. IT ALSO DOCUMENTS THAT, IF HYDROCARBON EMISSIONS FROM INCOMPLETE COMBUSTION (DUE TO THE LOW PROCESSING TEMPERATURE) WOULD BE A PROBLEM, THE GAS FLOW RATE SUBJECT TO 'POST TREATMENT' IN THE FORM OF AN AFTER BURNER WOULD BE VERY SMALL AND THE ENERGY REQUIRED FOR SUCH PROCESS WOULD BE ON THE ORDER OF 340,000 BTU PER TON OF SAND PROCESSED.

THUS, IF WE COMBINE ENERGY REQUIREMENT FOR SAND DRYING AND AFTER BURNER, WE WOULD HAVE A TOTAL ENERGY CONSUMPTION OF 700,000 BTU PER TON OF SAND PROCESSED. THIS IS, AT A MINIMUM, 30% LOWER THAN HIGH TEMPERATURE PROCESSING AND IN ALL LIKELIHOOD 50% OR MORE LOWER! A PROPER EVALUATION ABOUT ENERGY CONSUMPTION CAN ONLY BE ESTABLISHED IF WE DOCUMENT ALL ENERGY STREAMS AS PER ENCL. A5. THERE ARE NO KNOWN PUBLICATIONS WHERE THIS HAS BEEN DONE. HOWEVER, FROM NUMEROUS PAPERS IT CAN BE GLEANED THAT WHILE ENERGY CONSUMPTION RATES OF 106 BTU PER TON OF SAND ARE FREQUENTLY QUOTED, ACTUAL CONSUMPTION RATES IN OPERATING SYSTEMS ARE SIGNIFICANTLY HIGHER. THE AUTHOR OF THE REPORT 'SAND RECLAMATION CONCEPT DEFINITION STUDY' (GAS RESEARCH INSTITUTE, OCTOBER 1990) STATES ON PAGE 51:

'4. HEAT BALANCES ON MANY UNITS DO NOT APPEAR TO BE REALISTIC. ....'

THE QUESTION STILL REMAINS: DO WE NEED POST TREATMENT OF POC? IN A SECOND TEST, THE FOLLOWING DATA WAS ESTABLISHED:
POC COMPOSITION: 4.1% CO2; 14.1% O2; 0% CO [USING AN ORSAT APPARATUS]. THIS INDICATES A REASONABLE COMBUSTION EFFICIENCY. O2 LEVELS ARE ACTUALLY LOWER THAN THOSE REPORTED FROM FLUID BED SYSTEMS WITH THEIR HIGH PROCESSING TEMPERATURE. THIS DOES NOT SURPRISE BECAUSE TURBULENCE IN THIS EQUIPMENT IS MUCH HIGHER AND THE TEMPERATURE GRADIENT DUE TO DIRECT FLAME IMPINGEMENT AT VERY LOW EXCESS AIR RATES MUCH HIGHER. THUS, THE GOOD EMISSION VALUES REPORTED FROM FLUID BED SYSTEMS WHICH ARE GENERALLY MEASURED AT THE CLEAN AIR EXIT ARE THE RESULT OF DILUTION. IF THE CONTAMINANT LEVEL WOULD BE EXPRESSED AT A CONSTANT O2 DILUENT RATE, FLUID BEDS AND ROTARY KILNS WOULD HAVE CLEARLY HIGHER EMISSION RATES.

THE POC ANALYSIS PERFORMED IN ONE SPECIFIC TEST WHEN SAMPLING AT POINT "B" AS SHOWN IN ENCL. A2 RESULTED IN A HYDROCARBON EMISSION OF

34 MG/M3, EXPRESSED AS METHANE EQUIVALENT. THIS WAS EQUIVALENT TO 6.6 LBS METHANE PER 106 LBS PROCESSED SAND. AS WAS SHOWN IN ENCL. A4, 106 LBS SAND CORRESPONDED TO 500,000 LBS POC OR, IN OTHER WORDS, HYDROCARBON EMISSIONS (EXPRESSED AS METHANE EQUIVALENT) AMOUNTED TO 13 LBS PER 106 LBS POC.

IT MUST BE RECALLED THAT THIS CONTAMINANT LEVEL WAS MEASURED IN THE UNDILUTED POC STREAM PRIOR TO DUST FILTER. IT IS SAFE TO ASSUME THAT A PORTION OF THIS CONTAMINANT WOULD BE ADSORBED ONTO THE DUST PARTICLES COLLECTED IN A CLOTH FILTER AND CONSEQUENTLY, HYDROCARBON CONTAMINANTS DISCHARGED TO THE ENVIRONMENT CAN BE ESTIMATED TO BE LESS THAN 6 LBS METHANE EQUIVALENT PER 1,000,000 LBS POC.

WE MUST NOW CONSIDER WHAT THE EFFECT WOULD BE IF AN EFFORT WOULD BE MADE TO FURTHER REDUCE THOSE CONTAMINANTS BY WAY OF AFTER BURNER. THE ENERGY REQUIRED FOR POST TREATMENT OF POC IS GIVEN IN ENCL. A4 AS 340,000 BTU PER TON OF SAND PROCESSED. IF WE EMPLOYED A THERMAL OXIDIZER FOR THIS APPLICATION, WE WOULD GENERATE FROM THE USE OF PROPANE AN ADDITIONAL LEVEL OF APPROX. 51 LBS CO2 PER TON OF SAND OR FROM THE USE OF NATURAL GAS 47.5 LBS CO2 PER TON OF SAND. THUS, POC POST TREATMENT WOULD GENERATE ON THE ORDER OF 25,000 LBS CO2 IN AN EFFORT TO ELIMINATE 6 TO 10 LBS HYDROCARBON CONTAMINANT (AS METHANE EQUIVALENT). THE JUSTIFICATION FOR THIS WOULD HAVE TO BE QUESTIONED.

HOWEVER, IT MUST BE STRESSED THAT THE BEFORE STATED NUMBERS NEED TO BE CONSIDERED WITH SOME CAUTION. THE POC TO SAND RATIO OF UNDER 1 FOR THIS TYPE SYSTEM VS. 5 AND MORE FOR FLUID BEDS AND ROTARY KILNS CAN BE TAKEN FOR GRANTED FOR ALL APPLICATIONS. HOWEVER, THE 'WASTE STREAMS', BOTH SOLIDS AND GASES, WILL VARY WITH APPLICATION.

SOLIDS MAY BE AS LOW AS 3-4% IN SOME CASES (HIGH QUALITY SANDS IN 'CHEMICALLY BONDED' APPLICATIONS) BUT COULD EASILY REACH 15% AND MORE IF THE PROCESSED SAND WOULD HAVE HIGH CLAY LEVELS (OR OTHER FINES WHICH MAY BE ADDED FOR SPECIFIC TECHNOLOGICAL REASONS).

THE GENERATION OF HYDROCARBON CONTAMINANTS DEPENDS ON THE CHEMICAL COMPOSITION OF THE BINDER USED. SOME (SUCH A SHELL RESIN) WILL GENERATE VERY LITTLE CONTAMINANT SINCE THE COMPOUNDS ARE QUITE HEAT RESISTANT. OTHERS, WITH HIGHER LEVELS OF SOLVENTS, MAY GENERATE MORE. AT ANY RATE: THE PROCESSING AT TEMPERATURES OF APPROX. 400 °F WILL ALWAYS GUARANTEE THAT THE MAJORITY OF THE

CONTAMINANT IS REMOVED AS SOLID WASTE AND NOT AS POC. IF POST TREATMENT OF POC WOULD BE REQUIRED, THIS COULD BE ACCOMPLISHED AT LOWER COST THAN IN ANY OTHER PROCESSING SYSTEM DUE TO THE INHERENT LOW POC TO SAND RATIO.

REFERENCE WAS MADE EARLIER TO A REPORT FROM MICHIGAN TECHNOLOGICAL UNIVERSITY WHERE A LEAD CONTAINING BINDER RESULTED IN LEAD BUILD-UP AND ULTIMATELY LEACHATE TOXIC SAND DUE TO AN ACCUMULATION OF LEAD. IN ANOTHER MICHIGAN FOUNDRY, USING THIS SAME TYPE OF BINDER, THE TECHNOLOGY DESCRIBED IN THIS SECTION WAS IMPLEMENTED AND THE SAND NEVER EXCEEDED A LEAD LEACHATE VALUE OF 1 PPM. THE MICHIGAN DEPARTMENT OF NATURAL RESOURCES REPORTED ABOUT THIS INSTALLATION WITH THEIR CASE STUDY #9303 OF NOVEMBER 1993 (AVAILABLE FROM OFFICE OF WASTE REDUCTION SERVICES, ENVIRONMENTAL SERVICES DIVISION, DEPARTMENTS OF COMMERCE AND NATURAL RESOURCES, PHONE (517)335-1178.

3 CONSIDERATION OF AN ALTERNATE TESTING METHOD

THE "STANDARD HANDBOOK OF HAZARDOUS WASTE TREATMENT AND DISPOSAL" [MCGRAW-HILL] PRESENTS IN FIG. 8.5.2 ON PAGE 8.69 THE LEACHING CHARACTERISTICS OF LEAD AS A FUNCTION OF PH. IT DOCUMENTS THAT SOLUBILITY OF LEAD INCREASES WITH BOTH HIGH AND LOW PH VALUES. THIS CERTAINLY MUST CAUSE US TO QUESTION THE PRESENT TCLP TEST WITH ONLY ONE TESTING POINT AT PH 5. ALSO, THIS FIGURE PRESENTS DATA FROM SAMPLES WITH DIFFERENT LEAD MASS CONTENTS AND INDICATES THAT THE LEAD LEACHATE VALUES DO INCREASE WITH INCREASING LEAD MASS CONTENTS. THIS LATTER STATEMENT IS IN CONTRAST TO FINDINGS IN THE US FOUNDRY INDUSTRY.

IN 1980 A STUDY WAS CONDUCTED BY EPA AND DATA WAS SHARED WITH THE UNIVERSITY OF WISCONSIN IN MADISON WHICH INVESTIGATED LEACHATE BEHAVIOR FROM LEAD BEARING FOUNDRY WASTES. THE FULL INVESTIGATION IS CONTAINED IN THE 1981 TRANSACTIONS OF THE AMERICAN FOUNDRYMEN'S SOCIETY, PAGES 767 TO 786. ONE OF THE IMPORTANT FINDINGS WAS (ITEM 5 OF CONCLUSIONS):

'THERE WAS BASICALLY NO RELATIONSHIP BETWEEN THE PERCENTAGE OF CADMIUM OR LEAD RELEASED IN THE EP TEST AND THE CONCENTRATION OF THAT METAL IN THE WASTE'.

THUS, A MASS DETERMINATION OF LEAD IN THE FOUNDRY WASTE WOULD NOT SERVE AS A SIMPLER METHOD TO DETERMINE POTENTIAL

ENVIRONMENTAL RELEASES OF THIS SUBSTANCE.

THE FACT THAT THE INTERRELATIONS WITH RESPECT TO MIGRATION OF LEAD (OR OTHER METALS) VIA LEACHATE ARE QUITE COMPLICATED ARE ALSO CONFIRMED IN THE 1993 ANNUAL REPORT OF THE GERMAN ENVIRONMENTAL AUTHORITY ['UMWELT BUNDESAMT']. THIS REPORT COMMENTS ON PAGES 280/281 EXTENSIVELY ON THIS TEST. IT IS CLEARLY STATED THAT THE 'DANGER POTENTIAL' IS NOT PRIMARILY A FUNCTION OF THE MASS CONTENT OF THE CONTAMINANT IN A WASTE STREAM BUT IS SIGNIFICANTLY INFLUENCED BY ITS 'MOBILITY'. A NUMBER OF DIFFERENT (PROPOSED) TEST APPROACHES ARE DESCRIBED WHICH, AMONGST OTHERS, AIM AT BETTER PREDICTING LONG TERM STABILITY OF POTENTIALLY DANGEROUS WASTE CONSTITUENTS. ONE ASPECT OF GREAT IMPORTANCE IS THAT THE LEACHATE TEST ACCORDING TO DIN 38414-S4 IS PERFORMED WITH DISTILLED WATER AND NOT WITH ACETIC ACID. THIS DIFFERENT LEACH MEDIA WOULD GREATLY CHANGE THE RESULTS OF THE LEACHATE TEST.

REFERRING BACK TO THE BEFORE MENTIONED 1981 STUDY PUBLISHED IN THE AFS TRANSACTIONS, WE FIND UNDER CONCLUSIONS:

'3. THE EXTRACTION OF CADMIUM AND LEAD WAS HIGHLY DEPENDENT ON THE PH OF THE SOLUTION. USING THE EP TEST PROCEDURE, BUT USING DISTILLED WATER AS THE EXTRACTION MEDIA INSTEAD OF ACETIC ACID, THE CUPOLA DUSTS OR SLUDGES FROM ONE FOUNDRY WERE FOUND TO BE EP TOXIC WITH RESPECT TO CADMIUM. NO SAMPLES WERE TOXIC WITH RESPECT TO CHROMIUM OR LEAD. ......'.

THESE REMARKS ARE NOT MEANT TO SUGGEST THAT WE SHOULD FOLLOW THE APPROACH PRACTICED IN GERMANY WITHOUT CAREFUL CONSIDERATION OF ALL RAMIFICATIONS. HOWEVER, IT SHOULD BE HIGHLIGHTED THAT A COUNTRY SUCH AS GERMANY THAT IS CERTAINLY CONCERNED ABOUT ENVIRONMENTAL SAFETY IS APPLYING A STANDARD WHICH PLACES A MUCH LESS ONEROUS BURDEN ON ITS INDUSTRY WHICH COMPETES HEAD ON WITH NORTH AMERICAN COMPANIES - AND OBVIOUSLY WITHOUT SACRIFICING ENVIRONMENTAL SAFETY.

CERTAINLY, IN THE ABSENCE OF SUBSTANTIATING DATA, NO DECISIONS CAN (OR SHOULD) BE MADE. HOWEVER, VALUABLE DOCUMENTATION ALREADY EXISTS.

THE UNIVERSITY OF MICHIGAN-DEARBORN CONDUCTED EXTENSIVE STUDIES WITH RESPECT TO THE LEACHATE BEHAVIOR OF SANDS FROM BRASS AND BRONZE FOUNDRIES. A NUMBER OF PAPERS WERE PUBLISHED ON THIS SUBJECT

IN THE EARLY EIGHTIES AND ONE PAPER, PUBLISHED IN THE 1987 TRANSACTIONS OF THE AMERICAN FOUNDRYMEN'S SOCIETY, IS APPENDED AS ENCL. B TO THIS COMMENT.

THE AUTHORS POINT OUT THAT THE LOGIC FOR SUGGESTING ACETIC ACID LEACHING IS PREDICATED UPON THE ASSUMPTION THAT THE SAND WOULD BE MIXED WITH TRASH AND GARBAGE IN A MUNICIPAL LANDFILL AND THAT ACETIC ACID MIGHT BE GENERATED AS A DECOMPOSITION PRODUCT OF THE COMMINGLED ORGANIC WASTE (PAGE 712). THE AUTHORS ALSO STATE (PAGE 712):

'THAT IS TO SAY, THE LEACHABILITY IS NOT ONLY A FUNCTION OF THE PH BUT IS ALSO RELATED TO THE AMOUNT OF ACETATE ION SINCE ITS PRESENCE IS SOLELY DEPENDENT UPON THE ACID ADDITION'.

THE AUTHORS THEN PROCEED TO SUGGEST (PAGE 715) THAT A MORE LIKELY SCENARIO MIGHT BE THE EXPOSURE OF DEPOSITED WASTE TO SULFURIC AND NITRIC ACID FROM ACID RAIN. A TEST WAS THEREFORE CONDUCTED WITH 'AN ARTIFICIAL ACID RAIN'. CONCLUSIONS REACHED FROM THIS TEST WERE:

'IN ALL CASES THE ACID RAIN LEACHES LESS LEAD THAN THAT FOUND FROM THE EP TOXICITY TEST. THE MOST SENSITIVE LEAD FORM TO SYNTHETIC ACID RAIN LEACHING WAS PBO. HOWEVER, ONLY 16.4% OF THE LEAD WAS EXTRACTED BY THE ACID RAIN WHEN COMPARED TO THE EP TOXICITY TEST'.

'SINCE THE PH OF ACID RAIN VARIES IN DIFFERENT PARTS OF THE COUNTRY, A TEST AT PH OF 3.0 HAS ALSO BEEN CONDUCTED FOR THE CDA 83600 ALLOY. THE SAME VALUE OF 6 PPM LEAD HAS BEEN OBTAINED AT BOTH 3.0 AND 5.0 PH LEVELS'.

'THESE DATA SUGGEST THAT A MONOFILL CONTAINING ONLY FOUNDRY WASTE STREAMS MAY NOT LEACH SIGNIFICANT LEAD EVEN WHEN EXPOSED TO ACID RAIN'.

FIG. 8 (PAGE 716) OF THIS PAPER SHOWS COMPARISONS OF 'ACID RAIN' VS. 'STANDARD' LEACHING AND SUGGESTS THAT SANDS MIGHT INDEED BE CLASSIFIED AS NON-HAZARDOUS UNDER THIS TESTING PROCEDURE, USING 'ARTIFICIAL ACID RAIN' IN STEAD OF THE ACIDS NOW USED.

BASED ON THESE FACTS IT IS SUGGESTED THAT FOUNDRY WASTES BEING DEPOSITED IN MONOFILLS SHOULD BE EVALUATED USING A LEACHING MEDIA SUCH AS THE 'ACID RAIN' GENERATED IN THIS STUDY SINCE THE PRESENCE OF ACETIC ACID CAN VIRTUALLY BE RULED OUT. THIS WOULD BE AN

INTERMEDIATE SOLUTION.

IN THE LONGER TERM, A MORE CAREFUL INVESTIGATION MIGHT BE CARRIED ON TO EVALUATE THE LEACHATE PROCEDURES NOW APPLIED (AND UNDER INVESTIGATION) IN OTHER INDUSTRIALIZED COUNTRIES WHICH OBVIOUSLY RENDER QUITE DIFFERENT RESULTS FROM THE APPROACH TAKEN IN THE US AND PLACE A MUCH LESS COSTLY BURDEN ON INDUSTRY. THIS APPEARS TO BE THE CASE WITHOUT JEOPARDIZING THE SAFETY OF THE PUBLIC. IT WOULD CERTAINLY BE SUBJECT TO SOME SERIOUS DEBATE WHETHER WE CAN ASSUME THAT A HIGHLY INDUSTRIALIZED COUNTRY (AND DENSELY POPULATED) SUCH AS GERMANY WOULD DELIBERATELY PERMIT 'LAX STANDARDS' SUCH AS USE OF DISTILLED WATER AS A LEACHING MEDIA IF IT WOULD NOT GUARANTEE PROPER SAFEGUARDS FOR THE HEALTH OF ITS CITIZENS.

//ENDC1

RESPONSE

[The commenter expressed the following opinions concerning EPA's position with respect to treatment of foundry sand:

1. The commenter questioned EPA's concern regarding uncontrolled and impermissible releases of lead into the atmosphere as a result of treatment of foundry sands in high temperature thermal devices. The commenter stated that the Clean Air Act (CAA) 1990 emission limitations for thermal reclaimers, and 40 CFR Part 60, Subpart UUU (requirement for continuous opacity monitoring for particulates) "govern and control the operation of thermal reclaimers" and therefore, the commenter assumes that uncontrolled releases of lead will be avoided.

2. The commenter asserted that low temperature thermal processing is viable for treatment o foundry sand and presented various technical points to illustrate that hydrocarbon emissions could be readily controlled.

3. The commenter suggested that EPA use an alternative testing method to demonstrate leaching potential of metals such as a leach test using sulfuric or nitric acid to demonstrate the acid rain scenario, rather than the simulation of acetic acid generation via the EP toxicity test using acetic acid.

With respect to the uncontrolled release of lead into the atmosphere, the Agency remains concerned about the volatilization of lead and the potential for releases of lead to the atmospher during thermal treatment or reclamation of foundry sand. In the Phase III LDR rule the Agency stated that combustion of inorganics violates EPA's policy unless the combusted waste contains toxic organics or has significant organic composition.

Regarding the commenter's assertion that low temperature thermal processing is viable for treatment of foundry sand, the Agency notes that the treatment standards finalized in today's rulemaking are concentration-based and not technology-based. Therefore, any type of treatment technology can be used to meet the treatment standards provided the treatment unit, if required, i properly permitted. EPA also notes that to the extent the process involves solely the recovery of metals (as defined in 266.100), metal recovery devices are not presently subject to RCRA regulation. This assumes that the device involved is an industrial furnace.

Regarding the comment on test methods, EPA disagrees with the commenter's assertion that an alternative testing method in lieu of the TCLP should be allowed for assessing the potential leaching of iron-treated foundry sand. The Agency has established the TCLP as the required method for determining whether a waste will be considered toxicity characteristic hazardous (40 CFR 261.24(a)). EPA's determination of the use of the TCLP was finalized on March 29, 1990 (55 FR 11798). This issue is not being reopened in this rulemaking. However, EPA reviewed the suitability for testing the leachability of lead in foundry sand and continues to believe that TCLP testing is appropriate for determining whether the waste meets the treatment standards. This issue is discussed in the Technical Memorandum entitled "Iron Dust Treatment of Lead-Bearing Foundry Sand," dated September 15, 1995, and can be found in the Administrative Record for this rulemaking.

Issue: FOUN1-005 Respondent: TTS

Dcn: PH3P005 Extension: CBI: N
Commenter: UNITED STEELWORKERS OF AMERICA

Comment Number: 00001

//COMM1
//RESPTTS
//SUBJFOUN1-005

PROBLEMS WITH TCLP TEST

ADDITION OF IRON TO D008 WASTE SAND MAY MASK THE PRESENCE OF LEAD IN TWO WAYS. FIRST, IRON IS MORE EASILY OXIDIZED THAN LEAD. UNDER THE CONDITIONS OF THE TCLP TEST, IRON MAY BE PREFERENTIALLY LEACHED OUT INTO SOLUTION, LEAVING THE LEAD IN AN INSOLUBLE, AND THEREFORE UNDETECTABLE, STATE. THE GIBBS FREE ENERGIES FOR THE RELEVANT REACTIONS AT T=298K ARE:

PB + 1/2 O2 PBO ■G = -28.9 KCAL

2 FE + 3/2 O2 FE2O3 ■G = -353.9 KCAL

WHILE THE NEGATIVE FREE ENERGIES INDICATE THAT BOTH REACTION ARE THERMODYNAMICALLY FAVORABLE, IN FACT ONLY THE OXIDATION OF IRON PROCEEDS AT A MEASURABLE RATE AT ROOM TEMPERATURE. (THIS IS WHY IRON OBJECT RUST WITHIN DAYS IF LEFT OUTSIDE, BUT LEAD PIPES IN ROMAN BATHS ARE STILL IN SERVICE). UNDER THE MILDLY ACIDIC CONDITIONS AND SHORT DURATION OF THE TCLP TEST, WE EXPECT THAT THE IRON OXIDATION WILL PROCEED MUCH MORE QUICKLY THAN THE LEAD OXIDATION, WITH THE RESULT THAT LESS LEAD WILL BE LEACHED OUT OF THE SAMPLE THAN IF EXCESS IRON WERE NOT PRESENT.

A SECOND PROBLEM WITH THE PRESENCE OF IRON IN THE TCLP TEST IS SPECTRAL INTERFERENCE WITH THE ANALYSIS OF LEAD. THE INSTRUMENTAL TECHNIQUES MOST LIKELY TO BE USED TO ANALYZE LEAD ARE GRAPHITE

FURNACE ATOMIC ABSORPTION (GFAA) AND INDUCTIVELY COUPLED PLASMA (ICP). THE WAVELENGTHS RECOMMENDED FOR LEAD IN EPA METHOD 239.1 (LEAD BY GFAA) ARE 283.3 NM, 217.0 NM, AND 261.4 NM. THE CONTRACT LABORATORY PROGRAM ICP METHOD FOR LEAD (BASED ON EPA METHOD 200.7) RECOMMENDS A WAVELENGTH OF 220.353. IRON HAS A LARGE NUMBER OF SPECTRAL LINES THAT MIGHT OVERLAP THE RECOMMENDED WAVELENGTHS FOR LEAD (SEE CRC HANDBOOK OF CHEMISTRY AND PHYSICS, 75TH EDITION, PP. 10-44 THROUGH 10-48). A LARGE AMOUNT OF IRON IN A SAMPLE BEING ANALYZED FOR LEAD COULD RESULT IN A POSITIVE INTERFERENCE, AND A RAISED DETECTION LIMIT FOR LEAD.

HAZARDS OF INADEQUATELY TREATED D008 WASTE SAND

WHEN D008 WATER IS "TREATED" BY ADDITION OF IRON, THE CHEMICAL AND PHYSICAL FORM OF THE WASTE IS NOT CHANGED. AT MOST, THE PROPENSITY OF THE LEAD TO LEACH INTO GROUND WATER IS REDUCED. BUT GROUND WATER IS NOT THE MOST IMPORTANT POTENTIAL ROUTE OF EXPOSURE TO LEAD IN SOLID WASTE. AS EPA HAS RECOGNIZED, "GENERALLY, THE GROUND WATER PATHWAY WILL NOT POSE A SIGNIFICANT RISK..." FROM LEAD IN SURFICIAL SOILS. [REVISED INTERIM SOIL LEAD GUIDANCE FOR CERCLA SITES AND RCRA CORRECTIVE ACTION FACILITIES, JULY 14, 1994]. INHALATION OF DUST AND DIRECT INGESTION OF SOIL, ESPECIALLY BY CHILDREN, ARE FAR MORE IMPORTANT ROUTES OF EXPOSURE TO LEAD IN THE GROUND. TREATED D008 WASTES, ESPECIALLY CONTAMINATED SOILS, COULD BE USED AS FILL, ROAD BASE, ETC., MAKING SUCH EXPOSURE ROUTES HIGHLY PLAUSIBLE.

THE TCLP DOES NOT MEASURE THE RISKS POSED BY DIRECT INGESTION OR DUST INHALATION, BUT ONLY THE PROPENSITY TO CONTAMINATE GROUNDWATER. CONSEQUENTLY, TREATMENT METHODS THAT SPECIFICALLY ALTER TCLP RESULTS WITHOUT REDUCING THE INGESTION AND INHALATION HAZARDS ARE NOT PROTECTIVE OF PUBLIC HEALTH /1. TREATMENT METHODS FOR D008, AND OTHER LEAD-BEARING WASTES SUCH AS K061 AND K069, SHOULD BE ACCEPTED ONLY IF THEY CHANGE THE CHEMICAL OR PHYSICAL FORM OF THE WASTE IN A WAY THAT SUBSTANTIALLY REDUCES THE HAZARD FROM DUST INHALATION AND DIRECT INGESTION.

PHOSPHATE TREATMENTS FOR D008

THE USE OF PHOSPHATE-BASED ADDITIVES AS TREATMENT FOR D008 WASTES RAISES THE SAME QUESTIONS AS THE IRON ADDITIVES AND SHOULD BE ADDRESSED IN THE SAME RULE. SUCH TREATMENT HAS BEEN PROPOSED FOR LEAD-CONTAMINATED SOILS THAT ARE CLASSIFIED AS D008 WASTES AT

THE REVERE SMELTING AND REFINING SITE IN WALKILL, NEW YORK, WHICH IS SUBJECT TO REMEDIATION UNDER RCRA CORRECTIVE ACTION. THE SAME TREATMENT METHOD HAS BEEN PROPOSED FOR SIMILAR MATERIALS AT THE AVANTI SITE IN INDIANAPOLIS, INDIANA, WHICH IS UNDERGOING A CERCLA REMOVAL ACTION. THE COMPANIES UNDERTAKING BOTH OF THESE CLEAN-UPS ARE SUBSIDIARIES OF RSR CORPORATION. OUR UNION REPRESENTS EMPLOYEES AT RSR'S INDIANAPOLIS PLANT AND IS ON STRIKE AGAINST A RELATED COMPANY, BAYOU STEEL CORPORATION, IN LAPLACE, LOUISIANA.

A COPY OF THE PROPOSED CORRECTIVE MEASURES PLAN FOR THE WALKILL, NEW YORK SITE IS ENCLOSED. THE TREATMENT INVOLVES THE ADDITION OF A PHOSPHATE FIXATION AGENT AND BUFFER, IN A POWDER FORM, TO LEAD-CONTAMINATE SOIL, FOLLOWED BY THOROUGH MIXING. ORDINARILY, WATER WOULD BE ADDED TO FACILITATE THIS REACTION, BUT THE WALKILL PROPOSAL NOTES ONLY THAT "MOISTURE WILL BE ADDED AS NEEDED FOR DUST SUPPRESSION." THE FIXATION AGENT/BUFFER AND CONTAMINATED SOIL ARE APPARENTLY MIXED IN A RELATIVELY DRY STATE.

CURRENT RESEARCH ON THE USE OF PHOSPHATE ROCK TO REMEDIATE LEAD CONTAMINATED SOIL/2 INDICATES THAT THIS TREATMENT IS NOT YET A MATURE TECHNOLOGY. COLUMN LEACHING STUDIES IN THE LABORATORY INDICATE THAT SOLUBLE LEAD IS REDUCED IN CONTAMINATED SOILS TREATED WITH PHOSPHATE. HOWEVER, THE REDUCTION IN SOLUBLE LEAD CAN BE AS SMALL AS 38%. THE IMPORTANT FACTORS THAT GOVERN THE FORMULATION OF INSOLUBLE LEAD MINERALS IN SUCH LABORATORY STUDIES (SUCH AS THE PHOSPHATE ROCK-TO-CONTAMINATED SOIL RATIO), ARE AS YET IMPERFECTLY UNDERSTOOD. THE BEHAVIOR OF LEAD IN CONTAMINATED SOIL TREATED IN SITU WITH PHOSPHATES CANNOT YET BE PREDICTED WITH CONFIDENCE. CONTROL SAMPLES (LEAD CONTAMINATED SOIL WITH NO PHOSPHATE ADDED) IN THE CITED STUDIES ALSO SHOWED DECREASES IN SOLUBLE LEAD OVER TIME. THIS RAISES QUESTIONS ABOUT THE ABILITY OF THE LABORATORY STUDIES TO REPRESENT REAL ENVIRONMENTAL CONDITIONS, AND WHETHER THE DECREASE IN LEAD CONCENTRATION IS COMPLETELY ATTRIBUTABLE TO THE PHOSPHATE TREATMENT.

OF COURSE, THE WHOLE DISCUSSION OF REDUCING LEAD LEACHING INTO THE GROUND OR SURFACE WATERS FROM CONTAMINATED SOILS DOES NOT ADDRESS THE MOST LIKELY EXPOSURE SCENARIOS. THE DUST INHALATION AND DIRECT INGESTION HAZARDS WOULD REMAIN EVEN AFTER PHOSPHATE TREATMENT. EVEN IF PHOSPHATE TREATMENT EFFECTIVELY REDUCES LEAD LEACHING UNDER REAL ENVIRONMENTAL CONDITIONS (WHICH HAS NOT BEEN ADEQUATELY DEMONSTRATED), THERE IS NO EVIDENCE OF LONG-TERM EFFECTIVENESS. IT MUST BE DEMONSTRATED THAT THE TREATED SOILS POSE

NO HAZARD FROM INHALATION OR INGESTION.

//ENDC1

RESPONSE

[The commenter made the following comments:

1. asserted that the addition of iron dust to D008 waste foundry sand may mask the presence of lead, and thus the D008 waste may be inadequately treated;
2. asserted that the TCLP analysis does not measure the risks posed by dust inhalation or ingestion; and
3. expressed skepticism about the effectiveness of phosphate treatment for D008 waste and had similar concerns with respect to phosphate treatment as with the addition of iron to D008 wastes.

The Agency agrees with the commenter that the addition of iron dust to D008 waste sand may mask the presence of leachable lead. The Agency reviewed several comments and research studies for and against the "impermissible dilution" designation for iron treatment of characteristi metal wastes, and has concluded that addition of iron metal, in the form of fines, filings, or dust fails to provide long-term treatment for lead characteristic metal wastes, regardless of their origin, and constitutes a form of "impermissible dilution." EPA notes that RCRA requires that the TCLP analysis for determination of TC hazardousness be determined at the point of waste generation (55 FR 11830 March 29, 1990). Further, EPA notes that the TCLP testing by the foundry industry to demonstrate whether the waste is in fact TC hazardous (and hence, require treatment) is typically performed after the addition of the iron dust. The argument that th addition of iron dust is part of the process generating the waste is not valid.

As shown by the field studies conducted by Dr. Drexler and Dr. Kendall, the addition of iron filing results in no modification of the physical, chemical, or biological character of the waste. The addition of irons filing facilitates the adsorption of soluble lead on to the iron surface. However, once the iron surfaces oxidize, the ability of the additive to scavenge soluble metals is diminished,which is a dilution effect - See Drexler Report, pp. 14, 16, 18. Therefore, this is a reversible reaction and is not permanent. In addition, adsorption alone is not a reliable method of permanently immobilizing lead. Therefore, in the long-term, the migration of hazardous constituents is not retarded and thus, the requirements of RCRA 3004(m) are not fulfilled.

The type of treatment that only masks the test but does not actually reduce hazardous constituent mobility to any meaningful extent is not a type of waste management that can be said to minimize threats to human health and the environment. Therefore, the Agency, in today's final Phase IV rule, is promulgating regulatory language that confirms that the practice of iron addition as the sole form of treatment for lead in characteristic metal wastes is a type of impermissible dilution.

The Agency is also codifying this determination by amending 40 CFR 268.3 to read as follows:

40 CFR 268
§ 268.3 Dilution prohibited as a substitute for treatment

* * *

(d) It is a form of impermissible dilution, and therefore prohibited, to add iron filings or other metallic forms of iron to lead-containing hazardous wastes in order to achieve any land disposal restriction treatment standard for lead. Lead-containing wastes include D008 wastes (wastes exhibiting a characteristic due to the presence of lead), all characteristic wastes containing lead as an underlying hazardous constituent, listed wastes containing lead as a regulated constituent, and hazardous media containing any of the aforementioned lead-containing wastes.

* * *

In response to the commenter's remark about the TCLP test, EPA has established the TCLP as the required method for determining whether a waste is a toxicity characteristic hazardous waste (40 CFR 261.24 (a)). The TCLP test is designed to reflect the potential for the waste to leach at levels that pose a threat to human health and the environment. EPA's determination of the appropriateness of the use of TCLP was finalized on March 29, 1990 (55 FR 11798). This issue is not being reopened in this rulemaking. However, EPA reviewed the suitability for testing the leachability of lead in foundry sand and continues to believe that TCLP testing is appropriate for determining the characteristic of hazardousness for metal-bearing wastes. This issue is discussed in the Technical Memorandum entitled "Iron Dust Treatment of Lead-Bearing Foundry Sand," dated September 15, 1995, and can be found in the Administrative Record for this rulemaking. The Agency agrees with the commenter that the TCLP test does not measure the risks posed by direct ingestion. However, TCLP test is appropriate for testing materials placed in a landfill, since the principal threat to the environment is the leaching of toxic materials.

The Agency acknowledges the commenter's points relating to the phosphate treatment of foundry sands. However, because the Agency has inadequate data with respect to phosphate treatment, the Agency is not addressing the issue of phosphate-based additives as treatment for D008 wastes in this rulemaking. However, the Agency notes that any type of treatment including phosphate treatment of foundry sands, that temporarily masks the test methods and does not result in long-term treatment would be considered impermissible dilution.

Issue: FOUN1-009 Respondent: TTS

Dcn: PH3P009 Extension: CBI: N
Commenter: CYANOKEM

Comment Number: 00003

//COMM3
//RESPTTS
//SUBJFOUN1-009

CLASSIFICATION OF ADDITION OF IRON DUST AS IMPERMISSIBLE DILUTION

CYANOKEM SUPPORTS EPA'S PROPOSAL TO CLASSIFY AS IMPERMISSIBLE DILUTION THE USE OF IRON DUST OR FILINGS AS STABILIZING AGENTS FOR CERTAIN CHARACTERISTIC WASTES. CYANOKEM AGREES FULLY WITH EPA'S DISCUSSION IN THE PREAMBLE AT PAGE 11731 AND ADDS FURTHER THAT NO CHEMICAL REACTION OR POZZOLANIC REACTION IS POSSIBLE FROM IRON DUST OR FILINGS. THEREFORE MICROENCAPSULATION OR STABILIZATION IS NOT TAKING PLACE, ONLY DILUTION. THERE IS NO CHEMISTRY THAT CAN BE CONTRIVED TO JUSTIFY THAT METALS SUCH AS LEAD ARE BEING PERMANENTLY BOUND IN A NON-LEACHABLE MATRIX, WHEN USING IRON DUST OR FILINGS AS A STABILIZING AGENT.

CYANOKEM HAS ENCOUNTERED MANY CASES WHERE GENERATORS HAVE AVOIDED TREATMENT COSTS BY ADDING IRON TO THEIR METAL AND CYANIDE BEARING WASTE STREAMS. THIS PROVIDES THE SHORT TERM ABILITY TO FOOL THE TESTS FOR BOTH AMENABLE CYANIDE AND LEACHABLE METALS. EPA'S ADOPTION OF A TOTAL CYANIDE TREATMENT STANDARD HAS ESSENTIALLY SOLVED THE ISSUE OF MASKING EFFECTIVE TREATMENT OF CYANIDE USING IRON, BUT THE ISSUE OF METALS STILL REMAINS. CYANOKEM WELCOMES THIS PROHIBITION ON USE OF IRON DUST AND FILINGS, AND AGREES WITH EPA THAT IT WOULD PROMOTE MORE TREATMENT OF TOXIC METAL BEARING WASTES.

//ENDC3

RESPONSE

The Agency thanks the commenter for supporting EPA's position on the issue of designating the addition of iron dust to D008 waste sand as impermissible dilution. The Agency reviewed several comments (from Phase III and Phase IV NODA) and research studies for and against the "impermeable dilution" designation for iron treatment of characteristic lead wastes, and has concluded that addition of iron metal, in the form of fines, filings, or dust fails to provide long-term treatment for D008 characteristic metal waste, regardless of their origin, and constitutes a form of "impermissible dilution." Therefore, the Agency, in today's final Phase IV rule, is promulgating regulatory language that designates addition of iron filings to characteristic lead wastes as "impermissible dilution."

Issue: FOUN1-010 Respondent: TTS

Dcn: PH3P010 Extension: CBI: N
Commenter: NIBCO, INC

Comment Number: 00001

//COMM1
//RESPTTS
//SUBJFOUN1-010

LONG TERM TREATMENT

TO VERIFY LONG TERM TREATMENT. TWO OPTIONS WERE AVAILABLE. THE FIRST WAS THE LABORATORY APPROACH OF PERFORMING THE TCLP OR THE PREVIOUS EP-TOXICITY TEST, EACH INTENDED TO PREDICT THE WORST CASE SCENARIO FOR 100 YEARS OF STORAGE IN AN IMPROPERLY DESIGNED AND OR MANAGED MUNICIPAL LANDFILL. MATERIALS STABILIZED WITH METALLIC IRON HAVE CONSISTENTLY PASSED THESE TESTS.

TO FURTHER THIS WORST CASE APPROACH, MULTIPLE LEACHING PROCEDURES HAVE BEEN PERFORMED UNDER SEVERAL PROTOCOLS. ONE PROCEDURE WAS PERFORMED ON EXTRACTS USING SW-846 METHOD 1390 IN WHICH THE WASTE SAMPLES WERE EXTRACTED ACCORDING TO THE EXTRACTION PROCEDURE TOXICITY TEST, FOLLOWED BY 4 ADDITIONAL SYNTHETIC RAIN EXTRACTIONS. THE RESULTS OF THESE TESTS CAN BE FOUND IN APPENDIX A SECOND PROCEDURE SERIALLY SUBJECTED A SAMPLE OF WASTE SAND TO 5 SUCCESSIVE TCLP TESTS. THE CONCLUSION REACHED ON PAGE TWO (2) OF THE REPORT WHICH IS ATTACHED IN APPENDIX F STATES THAT " THE SAND WAS STILL NON-HAZARDOUS AFTER FIVE SUCCESSIVE TOXICITY TESTS, USING THE MORE RIGOROUS TEST PROCEDURE."

AN ADDITIONAL STUDY WAS PERFORMED BY TURPIN, P. D., AND B. E. DUDZIK. 1987 "CASE STUDIES IN SUCCESSFUL FOUNDRY WASTE TREATMENT." -- AMERICAN FOUNDRYMEN'S SOCIETY (AFS) TRANSACTIONS, 95:695-698. THE AFS STUDY WAS REFERENCED ON PAGE 38 OF THE BATTELLE REPORT OF FEBRUARY 22, 1994. WHILE THE BATTELLE REPORT APPEARS TO BE MUCH OF THE BASIS FOR THE PUBLICATION IN THE FEDERAL REGISTER OF MARCH 2, 1995, THE RESULTS OF THE AFS STUDY DO NOT SUPPORT THE CONCLUSIONS REACHED BY

THE AGENCY. IN THE CITED AFS STUDY, "THE LEAD LEACHING FROM THE WASTE WAS CONTROLLED OVER NINE ACIDIC LEACHING STEPS IN THE EP MULTIPLE EXTRACTION PROCEDURE."

THE SECOND OPTION THAT CAN BE USED IS EXISTING FIELD STUDIES THAT HAVE BEEN CONDUCTED ON FOUNDRY SAND LANDFILLS THAT HAVE BEEN STABILIZED WITH IRON DUST; LANDFILLS THAT HAVE BEEN IN EXISTENCE SINCE THE MID 80'S (THE INCEPTION OF METALLIC IRON STABILIZATION). ONE SUCH CHARACTERIZATION WAS PERFORMED ON FOUNDRY WASTE DISPOSED AT THE NACOGDOCHES MUNICIPAL LANDFILL. THE CHARACTERIZATION WAS PREPARED BY RMT INC. -- MADISON, WISCONSIN FOR NIBCO INC., NACOGDOCHES TEXAS IN DECEMBER OF 1993. THE CONCLUSION REACHED IN THIS CHARACTERIZATION WAS THAT THE WASTE DISPOSED OF IN THIS LANDFILL IS NOT A HAZARDOUS WASTE. A COPY OF THE BODY OF THIS REPORT IS ENCLOSED IN APPENDIX G. THIS REPORT WAS SUBMITTED TO THE USEPA REGION VL IN DECEMBER OF 1993.

MASKING OF THE TCLP RESULTS

IT HAS BEEN SUGGESTED BY THE EPA THAT THE LEAD IN THE TCLP TEST IS BEING MASKED BY THE PRESENCE OF IRON OR OTHER TREATMENT CHEMISTRIES IT APPEARS THAT THE SUPPORTING DOCUMENTATION IS A LETTER WRITTEN TO MR. JOHN GAUTHIER OF US EPA, REGION 17 OFFICE OF SOLID WASTE DATED SEPTEMBER 8, 1992 FROM DATANET ENGINEERING, INC. OF BALTIMORE, MD. THE LETTER STATES THAT "ACCORDING TO GAIL HANSEN OF EPA OFFICE OF SOLID WASTE, THE PRESENCE OF IRON MAKES THE TCLP QUITE IMPRACTICAL AS ESTABLISHED BY SPIKED SAMPLES HAVING EXCEEDINGLY POOR RECOVERY RATES." A COPY OF THIS LETTER IS INCLUDED IN APPENDIX K. THIS STATEMENT BY MS. HANSEN HAS NOT BEEN SUBSTANTIATED AND NO TEST RESULTS WERE USED TO CONFIRM THE SUPPOSED STATEMENT. THE JUSTIFICATION FOR THE CLAIM THAT THE IRON DUST IS MASKING THE TCLP TEST IS THE IMPLICATION THAT WHEN THE SAMPLE IS SPIKED WITH A KNOWN AMOUNT OF DISSOLVED LEAD,(MATRIX SPIKE) THE RECOVERY RATE IS EXTREMELY LOW. ENCLOSED IN APPENDIX J ARE SAMPLES OF TCLP TEST RESULTS PERFORMED ON FOUNDRY SAND WITH IRON PRESENT. ALL OF THESE TESTS WERE RUN WITH MATRIX SPIKE ADDITIONS. THE RECOVERY RATES ON THE MATRIX SPIKE RANGED FROM 90°~O TO 105%. THESE EXCELLENT RECOVERY RATES CONTRADICT THE SUGGESTION THAT THE IRON MASKS THE ANALYTICAL DATA. AT NO TIME DURING NLBCO'S 10 YEARS OF EXPERIENCE WITH EP-TOXICITY OR TCLP TESTING WAS THERE ANY EVIDENCE OF POOR RECOVERY RATES ON MATRIX SPIKE ADDITIONS. THE ONLY APPARENT POTENTIAL FOR POOR RECOVERY WOULD OCCUR IF THE LAB SPIKED THE SAMPLE PREMATURELY (BEFORE FILTRATION) IN WHICH CASE THE TREATMENT

CHEMISTRY WOULD LIKELY CAUSE THE LEAD TO BE PRECIPITATED.

THE AGENCY STATED THAT "... THE ADDITION OF IRON HAS BEEN DEMONSTRATED TO RESULT IN FALSE NEGATIVES FOR LEAD..." WHILE THE SUGGESTION OF FALSE NEGATIVES APPEARS IN THE AFOREMENTIONED LETTER OF SEPTEMBER 8, 1992, NO SUPPORTING LAB DATA ACCOMPANIED THE LETTER. IN ADDITION, NOWHERE IN THE BATTELLE REPORT, OR ANY OTHER SUPPORT DOCUMENTATION HAS THIS DEMONSTRATION BEEN CONFIRMED. A PROPERLY PERFORMED TCLP TEST BY A COMPETENT LAB WILL YIELD ACCURATE DATA.

ENCLOSED IN APPENDIX L ARE COPIES OF TEST RESULTS PERFORMED BY THE US EPA HOUSTON BRANCH. MOST OF THESE TESTS WERE PERFORMED ON FOUNDRY WASTE STREAMS THAT HAD BEEN STABILIZED USING METALLIC IRON. THESE LAB REPORTS DO NOT SPECIFY ANY QA/QC DATA, WHICH WOULD SUGGEST THAT QA/QC PROCEDURES WERE PERFORMED WITH NO QUESTIONABLE RESULTS. ANY OTHER CONCLUSION WOULD SUGGEST THAT THESE TESTS WERE IMPROPERLY CONDUCTED AND ARE THUS NOT ACCEPTABLE TESTS.

IT APPEARS THAT THE ORIGINAL PURPOSE OF THE TCLP TEST, I E. TO PREDICT POTENTIAL WORST CASE SCENARIO OF LEACHABILITY IN A MISMANAGED MUNICIPAL SOLID WASTE LANDFILL DURING THE NEXT 100 YEARS, HAS BEEN FORGOTTEN. THE ACETIC ACID IN THE TEST SIMULATES LANDFILL CONDITIONS TO WHICH THE WASTE FOUNDRY SAND WOULD BE SUBJECTED IN A MUNICIPAL WASTE LANDFILL. THE ADDITION OF IRON DUST (OR ANY OTHER APPROPRIATE CHEMISTRY) EFFECTIVELY PREVENTS THE LEAD IN THE LANDFILL FROM LEACHING EVEN IN THE PRESENCE OF ACETIC ACID, AS IS EVIDENCED BY THE RESULTS OF THE EXISTING TCLP TEST.

WEAK BONDS NOT LIKELY TO BE PERMANENT

PAGE 11731 STATES THAT "..THE AGENCY BELIEVES THAT THIS 'STABILIZATION' IS TEMPORARY, BASED UPON THE NATURE OF THE COMPLEXING. IN FACT, A REPORT PREPARED BY EPA ON IRON CHEMISTRY IN LEAD CONTAMINATED MATERIALS (FEB. 22, 1994), WHICH SPECIFICALLY ADDRESSED THIS ISSUE, FOUND THAT IRON LEAD BONDS ARE WEAK, ADSORPTIVE SURFACE BONDS, AND THEREFORE NOT LIKELY TO BE PERMANENT." THE REPORT IN QUESTION IS THE BATTELLE REPORT OF JANUARY 1994 WHICH WAS SUBMITTED IN AN INTERAGENCY MEMO ON FEBRUARY 22, 1994. A COPY OF THIS REPORT IS INCLUDED IN APPENDIX M.

IN ADDITION TO STABILIZATION THROUGH THE DEVELOPMENT OF SURFACE BONDS, IRON REACTS IN A LANDFILL SITUATION IN MUCH THE SAME WAY THAT ZINC ACTS IN GALVANIZED STEEL. THE PRESENCE OF METALLIC IRON

PREVENTS LEAD FROM LEACHING THROUGH A REDOX REACTION. NO CHEMICAL REACTION NEEDS TO TAKE PLACE UNTIL THE LEACHING CONDITIONS ARISE AT WHICH TIME THE PRESENCE OF IRON WILL EFFECTIVELY PREVENT LEAD FROM LEACHING.

THE CONCLUSION REACHED BY THE AGENCY DISREGARDED THE CONCLUSIONS REACHED IN THE BATTELLC REPORT. THE FOLLOWING ARE DIRECT QUOTATIONS FROM THE REPORT WHICH CONTRADICT THE AGENCY'S BELIEFS. "THE ATTRACTIVE FORCE OPERATING BETWEEN THE ADSORBED SPECIES ON THE ADSORBENT IS RELATIVELY WEAK, BEING ON THE SAME ORDER AS VAN DER WALLS FORCES."... "HOWEVER, LONG-TERM STABILITY OF THIS SITUATION IS UNKNOWN." ALTHOUGH THE BATTELLE REPORT STATES THAT THE ADSORPTIVE FORCES ARE RELATIVELY WEAK THE REPORT DID NOT REACH THE SAME CONCLUSION AS THE AGENCY THAT THE BONDS ARE "THEREFORE NOT LIKELY TO BE PERMANENT." THE AGENCY'S CONCLUSION ALSO NEGLECTED TO CONSIDER THE ADDITIONAL SURFACE PROCESS DISCUSSED ON PAGE 18 OF THE BATTELLE REPORT "IMMOBILIZATION OCCURS BY TWO SURFACE PROCESSES, ADSORPTION AND LATTICE SUBSTITUTION (HEM, 1977)."

BESIDES THE SURFACE PROCESSES, THE BATTELLE REPORT ALSO DISCUSSES THE EFFECTIVENESS OF THE FE-PB REDOX COUPLE (PAGE 92). "TABLE 7 SHOWS THE STANDARD STATE ELECTRICAL AND GIBBS FREE ENERGY CHANGES FOR THE REACTIONS WHICH DESCRIBE THE REDUCTION OF PB(II) TO PB(O) IN PURE WATER AND WHEN ACETATE IS PRESENT. IN THE ABSENCE OF ACETATE, REDUCTION OF PB(II) BY IRON METAL IS STRONGLY FAVORED..." THIS WOULD BE THE SITUATION IN A MONOFILL OR NEARLY ANY LAND DISPOSAL WITH THE EXCEPTION OF A MUNICIPAL LANDFILL WHERE THE ACETATE IS MORE LIKELY TO BE PRESENT. THE BATTELLE REPORT GOES ON TO SAY THAT "IN GENERAL, REDUCTION OF PB(II) IS LESS STRONGLY FAVORED WHEN ACETATE IS PRESENT, BUT THE REACTION WILL STILL PROCEED IN THE DIRECTION OF LEAD REDUCTION." THE BATTELLE REPORT CONFIRMS THAT LEAD REDUCTION IS LIKELY TO OCCUR, CONTRARY TO THE "BELIEFS" OF THE AGENCY. THE BATTELLE REPORT CONTINUES ON PAGE 99 TO CONCLUDE THAT "THE EQUILIBRIUM PHASES SHOWN IN FIGURES 5 THROUGH 8 ARE CONSISTENT WITH LEAD SOLUBILITY REDUCTION BY EITHER A REDOX COUPLE MECHANISM OR SORPTION ON FE(OH)3." THE BATTELLE REPORT REACHED NO CONCLUSIONS AS TO THE LONG TERM STABILITY OF THE IRON STABILIZATION, BUT DID SUGGEST AN ADDITIONAL STUDY TO ELIMINATE DATA GAPS. THESE SUGGESTIONS WERE APPARENTLY OVERLOOKED BY THE AGENCY IN AN ATTEMPT TO REACH A CONCLUSION WITHOUT THE BENEFIT OF THE FACTS OR SCIENTIFIC EVIDENCE.

IMPERMISSIBLE DILUTION

IN ITS PUBLICATION IN THE FEDERAL REGISTER OF MARCH 9. 1995, THE AGENCY PROPOSED TO CLARIFY THAT THE ADDITION OF IRON DUST IS 'IMPERMISSIBLE DILUTION'. THIS INTERPRETATION OF THE WORD DILUTION IS TOTALLY CONTRARY TO SCIENCE AND THE ENGLISH LANGUAGE. THE DEFINITION OF DILUTION AS FOUND IN 'CHAMBERS DICTIONARY OF SCIENCE AND TECHNOLOGY' IS AS FOLLOWS: "DILUTION (1) DECREASE IN CONCENTRATION" IF THE TREATMENT WERE TO BE BASED ON DILUTION A TEN PERCENT ADDITION OF IRON DUST SHOULD YIELD A TEN PERCENT REDUCTION OF THE TOXICITY CHARACTERISTIC. IN PRACTICE, TESTING HAS PROVEN THAT MATERIALS WITH A TCLP CHARACTERISTIC FOR LEAD AS HIGH AS 1000 MG/L BEFORE IRON ADDITION, YIELDS A TCLP FOR LEAD OF LESS THAN I MG/L WITH AS LITTLE AS L 0% IRON DUST ADDITION IT SHOULD BE OBVIOUS, TO EVEN THE MOST CASUAL OBSERVER, THAT SOME CHEMICAL MECHANISM OTHER THAN SIMPLE DILUTION IS OCCURRING.

IN DEFINING THE ADDITION OF 10% IRON DUST AS DILUTION. THE AGENCY IS REACTING CONTRARY TO IT'S ACCEPTED TREATMENT TECHNOLOGY USING LIME OR CEMENT KILN DUST (CKD). THESE TECHNOLOGIES REQUIRE AS MUCH AS 30°/O ADDITIONS TO BE EFFECTIVE AND WOULD MORE LIKELY BE CANDIDATES FOR THE DESIGNATION AS DILUTION. OF THE TWO TECHNOLOGIES, IRON DUST STABILIZATION NOT ONLY PROVIDES ACCEPTABLE TREATMENT, BUT MINIMIZES THE RESULTANT VOLUME OF THE WASTE DISPOSED.

INTERSTITIAL WATER WOULD LIKELY ACIDIFY

THE FOLLOWING PARAGRAPH IS ANOTHER EXAMPLE OF AN ASSUMPTION BEING MADE WITHOUT SCIENTIFIC BASIS. THE ASSUMPTION WAS SUBSEQUENTLY USED TO JUMP TO THE WRONG CONCLUSION. THE FOLLOWING PARAGRAPH IS CITED FROM THE MARCH 2, 1995 FEDERAL REGISTER. "FURTHERMORE, AS THIS IRON-RICH MIXTURE IS EXPOSED TO MOISTURE AND OXIDATIVE CONDITIONS OVER TIME, INTERSTITIAL WATER WOULD LIKELY ACIDIFY, WHICH WOULD POTENTIALLY REVERSE ANY TEMPORARY STABILIZATION, AS WELL AS INCREASE THE LECHABILITY OF THE LEAD FROM THE FOUNDRY SAND."

NOWHERE IS THE ISSUE OF ACID FORMATION, CAUSED BY THE PRESENCE OF IRON IN LANDFILLS, MENTIONED IN THE BACKGROUND DOCUMENTATION AND IS CONTRARY TO ACTUAL EXPERIENCE. ACID FORMATION ASSOCIATED WITH IRON COMES FROM HYDROLYSIS OF THE FERRIC IRON OR FROM THE OXIDATION OF FERROUS TO FERRIC IRON. AS EVIDENCED IN THE BATTELLE REPORT, STABILIZATION WITH METALLIC IRON CREATES REDUCING CONDITIONS IN WHICH IRON WOULD NOT BE OXIDIZED TO THE FERROUS TO FERRIC IRON. IN ADDITION, EXPERIENCE WITH THE TCLP TEST SHOWS THAT IRON NEUTRALIZES

THE ACETIC ACID (AS MAY BE EXPECTED TO BE FOUND IN A MUNICIPAL LANDFILL) AND RAISES THE PH RATHER THAN LOWERING IT AS SUGGESTED IN THE AGENCY'S CONCLUSION.

IN PRACTICE THE NATURAL BUFFERING CAPABILITIES OF FOUNDRY SAND, CAUSED BY THE CLAYS AND NATURAL BINDERS, HAS A TENDENCY TO STABILIZE THE PH IN THE NEUTRAL TO SLIGHTLY BASIC RANGE.

ALTERNATIVE TESTING PROCEDURES

BASED ON SUPPORTING DATA THAT THE RECOVERY RATES FOR SPIKED SAMPLES ARE WELL WITHIN ACCEPTABLE RANGES THERE IS NO EVIDENCE THAT THE TCLP TEST RESULTS ARE MASKED. IN FACT IT CONFIRMS THAT THE IRON IS DOING AN ACCEPTABLE JOB OF PREVENTING THE LEAD FROM LEACHING. THE TCLP WAS DESIGNED TO PREDICT WORST CASE SCENARIO OF MISMANAGED MUNICIPAL LANDFILL DISPOSAL AND ALTHOUGH IT IS EXTREMELY AGGRESSIVE IT APPEARS TO BE AN ACCEPTABLE TEST METHOD FOR DISPOSAL IN A MUNICIPAL SOLID WASTE LANDFILL.

WASTE FOUNDRY SAND IS COMMONLY DISPOSED OF IN A MONOFILL WHERE ACETIC ACID IS NOT LIKELY TO BE PRESENT. PERHAPS EITHER A DISTILLED WATER LEACHING PROCEDURE OR A SYNTHETIC ACID RAIN LEACHING PROCEDURE, WHICH MORE CLOSELY SIMULATES IN-SITU CONDITIONS. WOULD BE MORE APPROPRIATE. TO HELP SUBSTANTIATE THIS RECOMMENDATION, TEST RESULTS PERFORMED ON A LEAD BEARING, SLUDGE FROM A STORM WATER RETENTION BASIN ARE ENCLOSED. THE TEST RESULTS SHOW TCLP LEAD TO BE 4L.9 MG/L, WHILE ALTERNATIVE LEACHING METHODS SUCH AS THE STATE OF INDIANA LEACHING METHOD USING DE-LONIZED LEACHATE FLUID YIELDED <0.01 MG/L, THE SULFURIC ACID LEACHING PROCEDURE YIELDED <0.1 MG/L AND THE LEACHATE PROCEDURE USING RAINWATER YIELDED LEACHABLE LEAD AT 0.918 MG/L. I HOSE TESTS WERE ALL PERFORMED ON A SAMPLE THAT CONTAINED 1880 MG/L OF TOTAL LEAD. A COPY OF THESE LAB RESULTS IS INCLUDED IN APPENDIX N. THE ABOVE DATA SUPPORT THE CLAIM THAT THE TCLP IS NOT APPROPRIATE FAR ANY DISPOSAL METHOD OTHER THAN A MUNICIPAL SOLID WASTE LANDFILL. EXPERIENCE HAS SHOWN THAT IT IS ONLY THE AGGRESSIVE NATURE OF ACETIC ACID WHICH CAUSES THE LEAD TO LEACH. IN ANY OTHER DISPOSAL SCENARIO, A DISTILLED WATER OR SYNTHETIC RAINWATER LEACHATE TEST WOULD BE MORE APPROPRIATE.

AS FURTHER PROOF OF THE IMMOBILITY OF LEAD IN FOUNDRY SAND, ESPECIALLY IN MONOFILLS, MONITORING WELL DATA FROM A GWQAP AT THE NIBCO NACOGDOCHES SITE IS PROVIDED IN APPENDIX H. PRIOR TO THE HAZARDOUS WASTE REGULATIONS, WASTE FOUNDRY SAND WAS

ACCUMULATED IN ON-SITE SURFACE IMPOUNDMENTS AND LATER DRIED AND DISPOSED OF IN AN ON-SITE LANDFILL. THESE PONDS WERE ACTIVE FOR A TWENTY-FIVE TO THIRTY YEAR PERIOD, INITIALLY WITHOUT TREATMENT WITH IRON DUST. SUBSEQUENT TO THE HAZARDOUS WASTE REGULATIONS, PROCESS MODIFICATIONS WERE INSTALLED TO INTRODUCE IRON DUST INTO THE MATERIAL PRIOR TO GENERATION AS A WASTE. AS PART OF CLOSURE OF THESE SURFACE IMPOUNDMENTS AND LANDFILL A GROUND WATER QUALITY ASSESSMENT PROGRAM WAS IMPLEMENTED. THE RESULTS OF THIS PROGRAM CONFIRMED THAT NO LEACHING OF LEAD HAD OCCURRED AT THE SITE. DISSOLVED LEAD LEVELS, WERE EXTREMELY LOW IN ALL OF THE MONITORING WELL SAMPLES. IN FACT, MOST OF THE WATER SAMPLES TAKEN FROM THE ACTUAL POND WATER WERE ABLE TO MEET DRINKING WATER CRITERIA FOR LEAD. THIS REPORT WAS SUBMITTED TO THE TEXAS WATER COMMISSION (TWC) ON AUGUST 3, 1988. THE TWC CONCLUDED FROM THIS REPORT THAT "...COMPARISONS BETWEEN BACKGROUND AND DOWNGRADIENT WELLS INDICATE NO STATISTICALLY SIGNIFICANT DIFFERENCES FOR THE METALS CONCENTRATION." A COPY OF THE CONFIRMATION LETTER FROM SAMUEL B. POLE, CHIEF; HAZARDOUS AND SOLID WASTE ENFORCEMENT SECTION, HAZARDOUS AND SOLID WASTE DIVISION OF THE TWC IS ALSO ENCLOSED IN APPENDIX H.

OTHER AGENCY CONCERNS

OTHER CONCERNS RAISED BY THE AGENCY INCLUDE MIXING, SEPARATION, CONSISTENCY AND THE ABILITY TO CONTROL THE PROCESS. THESE CONCERNS APPEAR TO COME FROM COMPARISONS MADE BETWEEN FOUNDRY SAND AND LEAD PAINT REMOVAL WASTE. THE ISSUE RAISED ON PAGE 21 OF THE BATTELLE REPORT COMPARES FOUNDRY SAND AND LEAD PAINT REMOVAL WASTE AS BEING SIMILAR. CONCLUSIONS REACHED IN THE ASSESSMENT OF PAINT REMOVAL WASTE WOULD NOT BE APPROPRIATE IN ASSESSING THE EFFECTIVENESS OF FOUNDRY SAND STABILIZATION. THE PAINT REMOVAL WASTE WOULD BE EXPECTED TO BE VERY DISSIMILAR IN SIZE AND HULK DENSITY TO THE STEEL SHOT, AND WOULD LIKELY SEPARATE DURING THE BLASTING OPERATION AS WELL AS DURING TRANSPORTATION AND DISPOSAL. THE STABILIZATION OF FOUNDRY SAND IS PERFORMED UNDER CONTROLLED CONDITIONS. THE SAND AND IRON ARE SIMILAR IN SIZE AND BULK DENSITY, AND ARE THOROUGHLY BLENDED IN AN ENGINEERED SYSTEM. FOLLOWING ARE TYPICAL FOUNDRY PRACTICES WHICH ASSURE A HETEROGENEOUS MIXTURE OF FOUNDRY SAND AND IRON DUST.

TECHNIQUE FOR ADDITION AND TESTING OF IRON

THE MATERIAL DISPOSED OF IN THE ABOVE MENTIONED CITY OF

NACOGDOCHES LANDFILL CAME FROM VARIOUS PROCESSES WITHIN NLBCO'S OPERATIONS. THE MAJORITY OF THE MATERIAL WAS GENERATED IRON THE CLOSURE OF THE LONG TERM ON-SITE SURFACE IMPOUNDMENTS AND LANDFILL. THE MATERIAL WAS MIXED WITH IRON UTILIZING SEVERAL ACCEPTED FOUNDRY PRACTICES FOR MATERIAL ADDITIONS AND MIXING INCLUDING SCREW FEEDERS, BELT CONVEYORS, MULLOR MIXERS, AND VOLUMETRIC ROTARY FEEDERS. RANDOM SAMPLES WERE GATHERED ON A REGULAR BASIS TO TEST FOR THE PRESENCE OF AN ACCEPTABLE AMOUNT OF IRON DUST. THE SAMPLES WERE WEIGHED AND DRIED. THE IRON WAS THEN REMOVED FROM THE SAMPLES USING A MAGNET ALLOWING FOR A RELIABLE FIELD DETERMINATION OF IRON DUST PERCENTAGE. NORMAL PROCEDURE WAS TO TEST FOR IRON DUST PERCENTAGE ON AN HOURLY BASIS FOR CONTINUOUS OPERATIONS AND ON EACH BATCH FOR BATCH PROCESSES.

QUALITY CONTROL

INITIAL QUALITY CONTROL PROCEDURES FOR THE ADDITION OF IRON DUST WERE NOT FORMALIZED. IT WAS DETERMINED THAT 2.5% TO 5% IRON WAS NEEDED TO ADEQUATELY TREAT MOST OF THE MATERIAL TO BELOW REGULATORY LIMITS. BECAUSE OF THE POTENTIAL IMPLICATIONS OF HAZARDOUS WASTE REGULATIONS, A GOAL OF 10% IRON WAS PLACED ON THE ADDITION SYSTEM TO PROVIDE A SUFFICIENT LEVEL OF SAFETY AND ALLOW FOR POTENTIAL UNCERTAINTIES IN THE MATERIAL MIX. WHILE UNTREATED FOUNDRY SAND WILL TYPICALLY YIELD A TCLP TEST OF LESS THAN L 00 MG/L FOR LEAD, CONCENTRATED WASTE STREAMS WITH AN INITIAL TCLP OF NEARLY 1000 MG/L WERE ABLE TO BE TREATED TO WITHIN REGULATORY LIMITS WITH THE 10% IRON ADDITION. AS THE PROCESS PROGRESSED, QUALITY CONTROL PROCEDURES WERE INITIATED TO FURTHER ASSURE PROPER ADDITIONS OF IRON DUST. ATTACHED IN APPENDIX I ARE COPIES OF AVERAGE AND RANGE CHARTS THAT WERE UTILIZED IN THE PROCESS FROM THREE SEPARATE WASTE STREAM INPUTS. THE CHARTS ARE A SAMPLE OF THE CHARTS USED DURING THE ACTIVE OPERATION OF THIS PROCESS.

TCLP TESTING

IN ADDITION TO IRON DUST PERCENTAGE TESTING, COMPOSITE SAMPLES WERE REGULARLY SENT TO A LAB TO PERFORM THE APPROPRIATE EP-TOXICITY OR TCLP TEST. THESE TESTS WERE PERFORMED APPROXIMATELY TWICE A MONTH. ATTACHED IN APPENDIX J ARE COPIES OF THE COVER PAGE OF THESE TESTS FOR 1995 UNTIL SUSPENSION OF OPERATION OF THE LANDFILL FOR DISPOSAL. THE TCLP FOR THESE SAMPLES RANGED FROM BELOW DETECTION TO 0.2 MG/L. THE PERCENT IRON IN THE SAMPLES AS REPORTED BY NIBCO BASED ON SEPARATION TESTS RANGED FROM 14.2% TO 22.6%. THESE RESULTS ARE WELL

ABOVE THE REQUIRED 10%, BECAUSE IT WAS DETERMINED THAT THE COST OF ADDITIONAL IRON WAS MINIMAL COMPARED WITH THE ADDED ASSURANCE OF SUFFICIENT TREATMENT.
//ENDC1

RESPONSE

NIBCO does not agree with EPA's classification of iron dust treatment of foundry sands as impermissible dilution, and made the following points:

1. Iron dust treatment provides long-term treatment of foundry sands and is not impermissible dilution as EPA asserts;

2. Data does not support EPA's position that lead is masked by the addition of iron;

3. EPA's conclusion about iron-lead bonds are not the same as the conclusion reached in the Battelle report, which, acknowledges weak iron-lead bonds, however, concludes that long-term stability is unknown;

4. NIBCO disagrees with EPA's assertion that over time when exposed to moisture and oxidative conditions, interstitial water would likely acidify and thus, reverse stabilization and increase leachability of the lead from the foundry sand;

5. Because waste foundry sand is commonly disposed of in a monofill, acetic acid is not likely to be present and therefore, an alternative testing procedure should be used;

6. NIBCO also disagrees with the agency's concern with regards to controlling the process such as blending and mixing. The commenter believed that foundry sand waste and wastes from lead paint removal operations are dissimilar and that comparisons of these wastes should not be used to characterize the foundry sand operations.

EPA disagrees with the commenter's position that iron dust treatment provides long-term treatment. The Agency believes that it is unlikely that a chemical reaction occurs when iron dust is added to foundry sands. Because the waste foundry sand would likely contain only lead, silica, microscopic pieces of castings, and binders (clays, phenols, and tars) from the molds, EPA is not convinced that the simple addition of iron would provide treatment for the lead or the organics (i.e., phenol and tar). While it may be argued that iron could form temporary and weak, ionic complexes with silica and/or phenol, so that when analyzed by the TCLP test the lead appears to have been stabilized; however, EPA believes that this "stabilization" is temporary, based upon the nature of the complexing. In a report by EPA on Iron Chemistry in Lead Contaminated Materials (Feb. 22, 1994), which specifically addressed this issue, EPA found that iron-lead bonds are weak, adsorptive, surface bonds. EPA believes that these iron-lead bonds are not likely to be permanent. Studies conducted by Dr. Drexler and Dr. Kendall also concluded that adding iron filings to spent foundry sand is not a permanent treatment for hazardous constituents, and indeed that "the lead is in mmo way altered or immobilized." Kendall Report p. 2. EPA continues to believe that if this iron-rich mixture is exposed to moisture and oxidative conditions over time, interstitial water would likely acidify, which could potentially reverse any temporary stabilization, as well as increase the leachability of the lead from th foundry sand.

Further, EPA continues to believe that the conditions exist that will allow such chemical reactions to proceed to the extent whereby the stability of the treated lead-bearing waste deteriorates which could result in lead leaching. The Battelle report's equilibrium diagrams indicate that dissolved species predominate at pH levels below 6, and lead would likely remain as lead metal at pH of 6 or greater. Further, the scientific literature has shown that under waterlogged conditions, naturally occurring lead becomes reduced and mobile (Hazardous Waste Treatment, 1983. Brown, Kirk, G. Evans and B. Frentrup, eds). In consideration of the above, EPA continues to believe that the addition of iron dust or filings to D008 waste foundry sand does not appear to provide, long-term treatment\stabilization.

The Agency has concluded that this form of stabilization is only a short-term solution, and that it is inadequate to minimize the threats posed by land disposal of metal-containing hazardous wastes. Because the short-term effect is a dilution phenomenon (Drexler Report, pp. 14, 16, 18), EPA, therefore considers this technology "impermissible dilution" in accordance with 40 CFR 268.3. Although the addition of iron dust or filings is considered treatment under 260.10, the Agency does not believe it is adequate treatment; but merely the addition of material as a substitute for adequate treatment and therefore constitutes impermissible dilution. See 40 CFR 268.3 (B), 54 FR at 48494 (November 1989), and 55 FR at 22532 (June 1, 1990). As discussed above, the Agency does not believe any reaction occurs, and that the simple addition of iron does not provide adequate or long-term, treatment.

The available data indicates that analytical masking (i.e., analytical interference) may not be a problem, as evidenced by the available matrix spike recovery data. EPA has studied the chemistry relative to this iron treatment process which indicates that when the mixture is dry there is no reaction at all. e.g., See Kendall Report, p.2. However, once acetic acid is added (during TCLP analysis) some oxidation reduction type chemistry may occur that may mask the lead from getting into solution and hence, not be revealed in analytical analysis. However, the Agency points out that the analytical method for lead is sufficient and it is during the extraction process that masking occurs. EPA believes that iron treatment masks the TCLP results in that it passes the TCLP test initially but may fail over the long-term. EPA also notes that RCRA requires that the TCLP analysis for determination of TC hazardousness be determined at the point of waste generation (55 FR 11830 March 29, 1990). EPA notes that the TCLP testing by the foundry industry to demonstrate whether the waste is in fact TC hazardous (and hence, require treatment) is typically performed after the addition of the iron dust. The argument that the addition of iron dust is part of the process is not valid and believes that the addition of iron dust or filings masks the presence of lead.

The commenter is correct in that the Battelle report did not state that the bonds are not permanent, but concluded that the long-term stability is unknown. However, the Agency remains unconvinced about the long-term stability of this technology. The Agency realizes that this technology has been in use only since the early 1980's and thus, there is little data available on long-term effectiveness. The Agency compiled information on two different studies conducted on this issue, one by Dr. John Drexler of the University of Colorado and the other by Dr. Douglas Kendall of the National Enforcement Investigation Center (NEIC). These studies found that even after treatment, high concentrations of lead remained available to the environment and also leached in the units receiving the spent foundry wastes (measured by TCLP testing). Therefore, these studies concluded that the addition of iron filings or iron dust to lead-contaminated spent foundry sands did not constitute adequate treatment of the waste. See the March 5, 1997 NODA (62 FR 10004) for a full discussion of these studies. The conclusions reached by these studies were peer reviewed by an expert panel. The peer reviewers agreed that adding iron filings to spent foundry sand is not treatment of hazardous constituents in the ssense of actually impeding lead mobility. The peer reviewers also found that the scientific data presented in the studies support the conclusions reached and the studies are based on sound scientific research and fact. Therefore, the Agency reaffirms its conclusion that the addition of iron filing constitutes impermissible dilution

The Agency is also codifying this determination by amending 40 CFR 268.3 to read as follows:

40 CFR 268
§ 268.3 Dilution prohibited as a substitute for treatment

* * *

(d) It is a form of impermissible dilution, and therefore prohibited, to add iron filings or other metallic forms of iron to lead-containing hazardous wastes in order to achieve any land disposal restriction treatment standard for lead. Lead-containing wastes include D008 wastes (wastes exhibiting a characteristic due to the presence of lead), all characteristic wastes containing lead as an underlying hazardous constituent, listed wastes containing lead as a regulated constituent, and hazardous media containing any of the aforementioned lead-containing wastes.

* * *

The Agency does not agree with the commenter's suggestion that an alternative analytical testing procedure be used since the waste is disposed of in a monofill. EPA has established the TCLP as the official required method for determining whether a waste is toxicity characteristic hazardous. EPA's determination of the use of the TCLP was finalized on March 29, 1990 (55 FR 11798). This issue is not being reopened in this rulemaking. However, EPA reviewed the suitability for testing the leachability of lead in foundry sand and continues to believe that TCLP testing is appropriate for determining the characteristic of hazardousness for metal-bearing waste streams. This issue is further discussed in the Technical Memorandum entitled "Iron Dust Treatment of Lead-Bearing Foundry Sand," dated September 15, 1995, and can be found in the Administrative Record for this rulemaking. With regard to the comment on the MELP, the Agency agrees that both TCLP and MELP are acceptable analytical procedures. However, the Agency notes that the MELP is designed to test the leachability of constituents on a longer term and therefore, a sample that passes the MELP is very unlikely to fail the TCLP. In addition, the Agency notes that the RCRA regulations, as stated in 40 CFR 261.4(a), require TCLP, test method 1311 to determine wether the leachate exhibits a hazardous characteristic.

With respect to the comment on the absence of current groundwater contamination, the Agency notes that studies have shown leachate testing to be an ineffective measure of long-term metal mobility and future monitoring may show contamination, should any landfill liner fail or contamination reach the monitoring well.

Issue: FOUN1-017 Respondent: TTS

Dcn: PH3P017 Extension: CBI: N
Commenter: THE TDJ GROUP, INC

Comment Number: 00001

//COMM1
//RESPTTS
//SUBJFOUN1-017

1) CRITICISM OF EPA WASTE CHARACTERIZATION PROCEDURES

AS YOU ARE AWARE, A PERFECT CHARACTERIZATION TEST FOR TOXICITY DOES NOT EXIST. IN AN EFFORT TO PROVIDE A REASONABLE CONSERVATIVE TEST THAT SIMULATES CONDITIONS IN AN ACIDIC LANDFILL, THE EPA IMPLEMENTED THE CURRENT TCLP TEST NOW USED TO CHARACTERIZE D008 WASTES. ALTHOUGH THE TCLP TEST REPLACED A PROCEDURE WHICH SIMULATED APPROXIMATELY 100 YEAR IN AN ACIDIC LANDFILL, THE SHORT-TERM NATURE OF THE TCLP TEST DOES NOT TAKE INTO ACCOUNT THE POSSIBILITY FOR SHORT AND MEDIUM TERM CHEMICAL CHANGE IN THE WASTE WHICH COULD LEAD TO AN UNACCEPTABLE RELEASE OF LEAD OR OTHER INORGANICS. IN ADDITION, THE ACIDIC NATURE OF THE TEST DOES NOT ALLOW CONSIDERATION OF THE PERFORMANCE OF THE WASTE IN A MORE ALKALINE ENVIRONMENT. THIS IS OF SOME CONCERN, SINCE THE D--9 BDAT RECOMMENDED BY TEN AGENCY INVOLVES THE USE OF BASIC SILICATE STABILIZATION TECHNOLOGIES, SUCH AS PORTLAND CEMENT, AND LEAD IS AMPHOTERIC. EXCESSIVE ELEVATION OF PH WITH NO OTHER CHANGES MAY CREATED CONDITIONS OF ELEVATED LEAD MOBILITY IN BASIC ENVIRONMENTS.

IT IS THE EXPERIENCE OF THE AUTHORS OF THIS LETTER THAT TESTING PROCEDURES CAN BE USED TO MAKE A SERIES OF POINTS FOR AND AGAINST CURRENT AGENCY TESTING METHODS, BUT MORE THOUGHTFUL AND CAREFUL APPLICATION OF VARIOUS AGENCY TEST METHODS SEEMS TO SUPPORT THE CONCENTRATION THAT THE TCLP OFFERS A REASONABLY CONSERVATIVE (BUT INCOMPLETE) VIEW OF WASTE STABILITY. FOR EXAMPLE, IN A RECENT FHWA REPORT (REVIEWED BY EPA STAFF), SAMPLES OF SILICATE AND IRON TREATED D008 WASTES WERE SUBJECTED TO SINGLE AND MULTIPLE TCLP TESTING AND MEP

TESTING.

SILICATE ADDITIONS TO ABRASIVE USED ON LEAD BASED PAINT CREATES A WASTE WHICH EXHIBITS LONG TERM STABILITY. THIS IS EVIDENT BY THE WASTE'S ABILITY TO WITHSTAND CYCLED ACIDIC ENVIRONMENTS IN FIVE SEQUENTIAL TCLP TESTS AND THE MEP TEST. IN BOTH CASES THE WASTE SHOWED NO TRENDS TOWARDS INCREASING LEAD LEACHABILITY.

IN THE SAME SET OF TESTS, IRON TREATED ABRASIVE WAS UNABLE TO SURVIVE THE MEP TEST, APPARENTLY DUE TO THE PROGRESSIVE CORROSION OF THE IRON FILLING USED IN THE WASTE DURING THE TEST. THIS SAME WASTE PASSED THE TCLP TEST, AND WAS CAPABLE OF PASSING MULTIPLE TCLP TESTS AS LONG AS THE TESTS WERE PERFORMED OVER A SHORT SPAN OF TIME.

THERE APPEARS TO BE SUFFICIENT INFORMATION AVAILABLE TO THE AGENCY IN PUBLISHED FORM THAT SUGGESTS THAT IRON TREATED WASTES WILL NOT REMAIN STABLE IN ACIDIC ENVIRONMENTS. IT ALSO SEEMS CLEAR THAT WE DO NOT HAVE CORRESPONDING TESTING DATA TO ADDRESS THE SAME ISSUE IN A PH NEUTRAL OR ALKALINE DISPOSAL ENVIRONMENT.

FROM THE STANDPOINT OF TESTING PROCEDURES, THE AUTHORS OF THIS LETTER SUGGEST THAT THE TCLP TEST IS NECESSARY BUT NOT SUFFICIENT FOR TESTING IRON TREATED D008 WASTES. THIS WASTE MATERIAL IS SOMEWHAT EXCEPTIONAL IN THAT WE CAN CLEARLY SEE THE PROCESS THAT WILL ALLOW THE MATERIAL TO FAIL (RUSTING OF THE IRON), AND WE NOTE THE INABILITY OF THE TEST TO SIMULATE THE SAME. RATHER THAN DAMNING THE EXISTING TESTING PROCEDURE, WE WOULD ADVISE THE AGENCY TO CONSIDER THESE WASTES AS A SEPARATE MATERIAL UNDER THE REGULATIONS, AND TO USE THAT STATUS TO MODIFY THE TESTING AND TREATMENT REQUIRED FOR LAND DISPOSAL.

2) ARGUMENTS SUGGESTING THAT THE PROPOSED RULING DOES NOT OR SHOULD NOT APPLY TO PARTICULAR CONDITIONS OF DISPOSAL

PRELIMINARY DATA FORM THE FOUNDRY INDUSTRY (OUTLINED IN THE AMERICAN FOUNDRYMANS SOCIETY RESPONSE) SUGGESTS THAT MONOFILLING OF THESE WASTES SHOWS NO EVIDENCE OF LEAD MOBILITY IN SOIL TESTS AND IN GROUNDWATER MONITORING. THESE DATA NEED TO BE UNDERSTOOD WITHIN THE CONTEXT OF THE LARGER PROBLEM THE AGENCY FACES. LIMITED DATA ON GROUNDWATER MONITORING FROM THE FOUNDRY INDUSTRY (BOTH HARD AND ANECDOTAL DATA) APPEAR TO SHOW LITTLE EVIDENCE THAT THE MOST COMMON LEADED ALLOYS IN USE BY THE INDUSTRY HAVE MIGRATED WHEN DISPOSED TO MONOFILLS. THESE DATA COULD INCLUDE EVIDENCE OF A LACK OF MOBILITY OVER PERIODS OF TIME THAT EXTEND BEFORE RCRA AND THE ADOPTION OF IRON

TREATMENT PRACTICES (PRE-1978). NO CONCLUSIVE DATA ARE AVAILABLE TO REFLECT THE PERFORMANCE OF IRON TREATMENT OVER DECADES, SINCE THE PRACTICE WAS FIRST INTRODUCED IN THE FOUNDRY INDUSTRY IN 1985. NO CONCLUSIVE DATA ARE AVAILABLE TO CLEARLY MODEL THE MOBILITY OR LACK OF MOBILITY OF COMMON FOUNDRY LEAD ALLOYS IN LESS ACIDIC LAND DISPOSAL ENVIRONMENTS. IT WOULD SEEM CLEAR, HOWEVER, THAT DISPOSAL OF IRON-TREATED BRASS CONTAMINATED FOUNDRY WASTES IN ALKALINE MONOFILLS SHOULD BE ANALYZED DIFFERENTLY THAN DISPOSAL OF SPENT LEAD-CONTAMINATED ABRASIVE IN ACIDIC LANDFILLS.

3) ARGUMENTS SURROUNDING POINT OF GENERATION ISSUES

POINT OF GENERATION ISSUES HAVE ALREADY SURFACED AS A MATERIAL PORTION OF THIS RULEMAKING.

IT SHOULD BE NOTED THAT PROCESS CHANGE FOR THE PURPOSES OF WASTE REDUCTION OR MOTIVATION IS ALREADY AN AREA OF SUBSTANTIVE ACTIVITY IN BOTH THE FOUNDRY AND STEEL MAINTENANCE INDUSTRIES. IN THE SUBJECT AREAS OF OPERATION (RECYCLING OF MOLDING SANDS, APPLICATION OF STEEL GRIT, APPLICATION OF SILICA BASED ABRASIVE WITH IRON ADDITIONS), IRON DUST AND/OR STEEL GRIT CAN SURVIVE THE ENTIRE USE ENVIRONMENT. IN SHORT, THIS MEANS THAT NO MATTER WHERE THE "POINT OF GENERATION" IS DEFINED BY THE AGENCY, IT WILL BE POSSIBLE TO ADD IRON DUST UPSTREAM OF THAT POINT, THEREBY AVOIDING SUBTITLE C REGULATION OF THE WASTE. IF THE AGENCY FEELS THAT THIS PROCESS OF WASTE CHANGE OR TREATMENT IS NOT AN ACCEPTABLE PRACTICE, USE OF POINT OF GENERATION ISSUES MAY NOT BE EFFECTIVE IN RESTRICTING THESE ACTIVITIES.

4) SUGGESTIONS THAT THE PROPOSED RULE DOES NOT PROMOTE WASTE MINIMIZATION

IF THE AGENCY ACTS TO DISCOURAGE THE USE OF IRON MATERIALS AS TREATMENT AGENTS, THIS MAY HAVE AN IMPACT ON THE SALE AND USE OF RECYCLABLE STEEL ABRASIVE IN STEEL MAINTENANCE AND DELEADING APPLICATIONS. ONE OF THE ARGUMENTS OFFERED IN THIS AREA IS THE SUGGESTION THAT RECYCLABLE STEEL GRIT REPRESENTS AN OPPORTUNITY TO MINIMIZE WASTES GENERATED THROUGH THE USE OF "NON-RECYCLABLE" ABRASIVE. IN TRUTH, ALL OF THE SLAG "NON-RECYCLABLE" ABRASIVE IS IN FACT, A RECYCLED WASTE MATERIAL IN ITS OWN RIGHT. THESE MATERIALS INCLUDE RECYCLED COAL SLAGS, COPPER SLAGS, STEEL SLAGS, AND NICKEL SLAGS. NO MATTER WHICH WAY THE AGENCY FINALLY RULES ON THIS MATTER, IT WILL BE PROVIDING SUPPORT FOR ONE OR MORE OF A SERIES OF RECYCLING EFFORTS.

WE WOULD MAKE A SERIES OF OBSERVATIONS AND CONCLUSIONS BASED ON THE ABOVE INFORMATION:

THE TCLP TEST IS A CONSERVATIVE, BUT IMPERFECT MEASURE OF HEAVY METALS MOBILITY POTENTIAL IN LANDFILLS;

THE TCLP TEST MAY NOT ACCURATELY REFLECT THE POTENTIAL MOBILITY OF HEAVYMETALS IN MONOFILLS AND NON-LANDFILL ENVIRONMENTS;

IRON TREATED WASTES FROM BOTH THE FOUNDRY INDUSTRY AND THE LEAD PAINT ABATEMENT OF STEEL STRUCTURES (SPENT ABRASIVE WASTE) ARE BEING DISPOSED IN SANITARY LANDFILLS WITH ACID LEACHATES PRESENT;

IN ACIDIC ENVIRONMENTS WITH SUFFICIENT MOISTURE AND OXYGEN, IRON WILL RUST AND THE TREATMENT REACTIONS WILL BE REVERSED;

IF THE LEAD COMPOUNDS ARE MOBILE WITHOUT TREATMENT, THEY WILL LEACH AFTER THE IRON IS OXIDIZED;

GOVERNMENT EFFORTS TO STOP THE PROCESS OF IRON DUST TREATMENT THROUGH AGGRESSIVE DEFINITION OF POINTS OF WASTE GENERATION WILL PROBABLY NOT BE EFFECTIVE;

STOPPING THIS TREATMENT PROCESS FOR LEADED WASTES WILL PROBABLY HAVE NOT IMPACT ON WASTE MINIMIZATION ACTIVITIES.

//COMM2
//RESPRIA
//SUBJREGR1

WHAT CAN THE AGENCY DO TO RESTRICT THESE IRON TREATMENT ACTIVITIES? IF THE OBSERVATION THAT POINT OF GENERATION IS NOT AN EFFECTIVE MEANS OF REGULATING THIS PRACTICE, THEN WE WOULD SUGGEST THAT THE GOVERNMENT CONSIDER LISTING IRON AND LEAD RICH WASTE STREAMS (FROM BRASS FOUNDRY CASTING SANDS, BRASS FOUNDRY STEEL GRIT CLEANING SYSTEMS, IRON TREATED SPENT ABRASIVE AND THE RESIDUE FROM MOBILE STEEL GRIT SYSTEMS USED IN LEAD PAINT ABATEMENT) AS HAZARDOUS, WITH A CLEARLY DEFINED PATH FOR DELISTING. OUR DATA SUGGEST THAT THERE ARE THREE POTENTIAL TYPES OF WASTE GENERATORS THAT WOULD BE IMPACTED BY SUCH A DECISION: LARGE FOUNDRIES WITH THEIR OWN MONOFILLS, SMALLER FOUNDRIES USING OFFSITE COMMERCIAL DISPOSAL FACILITIES, AND SAND BLASTING CONTRACTORS THAT MOVE FROM JOB SITE TO JOB SITE. LARGER FOUNDRIES WITH MONOFILLS ARE DISPOSING OF THE MATERIAL IN A POTENTIALLY LESS ACIDIC ENVIRONMENT AND

HAVE THE RESOURCES TO GO THROUGH A DELISTING PROCESS. SMALLER FOUNDRIES DO NOT HAVE THE ABILITY TO DELIST, BUT THE AGENCY COULD PRESCRIBE A METHOD OF TREATMENT (SILICATE STABILIZATION) NECESSARY TO DISPOSE OF THE MATERIAL. ABRASIVE APPLICATORS WORK MULTIPLE SITES IN A GIVEN YEAR, SO DESLISTING WOULD NOT BE AN OPTION. SINCE THIS IS THE AREA OF GREATEST USE OF IRON DUST TREATED WASTES, THIS WOULD DISCOURAGE THE PRACTICE.

BASED ON THE SPEED OF NEW TECHNOLOGY DEVELOPMENT IN THIS AREA, AS WELL AS THE AVAILABILITY OF EXISTING TECHNOLOGIES, THIS ACTION BY THE GOVERNMENT WOULD PROBABLY HAVE LITTLE ECONOMIC IMPACT ON THE REGULATED COMMUNITY. CURRENTLY METHODS NOT UTILIZING IRON TREATMENT IN THE ABRASIVE INDUSTRY NOW COST ABOUT THE SAME PER SQUARE FOOT OF PAINT REMOVAL AS METHODS UTILIZING THE PRACTICE OF IRON ADDITION. FOR EXAMPLE, THE DIFFERENCE IN COST OF PAINT REMOVAL BETWEEN IRON AND NON-IRON ADDITION IS ABOUT $0.15 TO $0.25 PER SQUARE FOOT (IRON ADDITION IS SLIGHTLY CHEAPER). ON A PROJECT WHERE THE AVERAGE COST OF PAINT REMOVAL TYPICALLY RUNS FROM $6.00 TO $15.00 PER SQUARE FOOT, A SMALL CHANGE IN THE COST OF DISPOSAL WILL NOT MATERIALLY AFFECT THE USE OF TECHNOLOGY.

//ENDC1

RESPONSE

The TDJ Group submitted comments making the following observations and conclusions:

1. The TCLP test is an imperfect measure of heavy metals mobility potential at landfills, monofills, and non-landfill environments;
2. Iron-treated foundry sands disposed of in alkaline monofills should be analyzed differently than spent lead-contaminated abrasives disposed of in acidic landfills;
3. Defining the point of generation will not be effective in stopping the use of the process to avoid Subtitle C jurisdiction; and
4. The proposed rule may not have an impact on waste minimization.

The Agency has determined that the TCLP test is the approved analytical procedure for determining whether a waste exhibits the toxicity characteristic for metal-bearing wastes. EPA's determination of the use of the TCLP was finalized on March 29, 1990 (55 FR 11798). This issue is not being reopened in this rulemaking. However, EPA reviewed the suitability for testing the leachability of lead in foundry sand and continues to believe that TCLP testing is appropriate for determining the characteristic of hazardousness for metal-bearing waste streams. This issue is further discussed in the Technical Memorandum entitled "Iron Dust Treatment of Lead-Bearing Foundry Sand," dated September 15, 1995, and can be found in the Administrative Record for this rulemaking.

In any case, the Agency is not reopening the issue of the proper test for determining toxicity. Rather, the issue is whether a particular method of treatment minimizes threats posed by land disposal of a hazardous waste. The ultimate conclusion in this proceeding is that addition of iron filings is an inadequate method for treating D008 wastes since lead is not immobilized. Rather, the analytic compliance method is blinded. This is a form of dilution. See also Drexler Report at pp. 14, 16, 18 (addition of iron filings results in a dilution effect, not actual immobilization).

As stated above the Agency has determined that the TCLP test is the approved analytical procedure for determining whether a waste exhibits the toxicity characteristic for metal-bearing wastes. Again, the issue in this proceeding is entirely different: evaluation of the adequacy of a type of treatment process. The Agency is not reopening the question of a method for identifying which wastes are hazardous, and comment responses are included only in the event a response to these unsolicited points is considered to be necessary. Regarding the point of generation issues, EPA notes that RCRA requires that the TCLP analysis for determination of TC hazardousness be performed at the point of waste generation (55 FR 11830 March 29, 1990).

EPA acknowledges the comment that curtailing treatment of lead-containing foundry sand by addition of iron dust process may not impact waste minimization activities.

Issue: FOUN1-040 Respondent: TTS

Dcn: PH3P040 Extension: CBI: N
Commenter: AMERICAN FOUNDRYMEN'S SOCIETY, INC

Comment Number: 00001

//COMM1
//RESPTTS
//SUBJFOUN1-040

IRON ADDITION TO FOUNDRY WASTE IS NOT DILUTION

EPA'S REFERENCE TO IRON FILINGS TREATMENT USED BY THE FOUNDRY INDUSTRY AS BEING IMPERMISSIBLE DILUTION IS NOT VALID. NO SUPPORTING DOCUMENTATION CITED IN THE FEDERAL REGISTER NOTICE JUSTIFIES THE EPA'S POSITION. THE REPORT, CITED BY EPA AS SUPPORTING IT'S POSITION IS BATTELLE'S "IRON CHEMISTRY IN LEAD CONTAMINATED MATERIALS" (DATED FEBRUARY 22, 1994, PREPARED FOR EPA S RISK REDUCTION ENGINEERING LABORATORY, CINCINNATI, OHIO AND REFERRED TO IN THIS LETTER AS THE BATTELLE REPORT). THIS REPORT SPECIFICALLY INDICATES DOSAGE RATES USED BY FOUNDRIES OF 1 TO 10% AS EFFECTIVELY LOWERING THE LEAD LEACHABILITY FROM THE ORIGINAL LEVEL OF WELL OVER 100 PPM TO LESS THAN 5 PPM IN THE WASTE TESTED. IF THE TWENTY-FOLD REDUCTION IN LEAD CONCENTRATIONS WAS SOLELY DUE TO DILUTION, AN 800% TO 5000% ADDITION WOULD BE REQUIRED, 10% WOULD NOT BE SUFFICIENT. IT IS A CHEMICAL REACTION, NOT SIMPLE DILUTION, THAT IS STABILIZING THE LEAD IN THE FOUNDRY WASTES. THE SCIENTIFIC AND TECHNICAL DISCUSSION OF THE CHEMICAL REACTIONS INVOLVED ARE CONTAINED IN COMMENTS SUBMITTED BY RMT, INC. REGARDING THE MARCH 2ND FEDERAL REGISTER.

IRON IS NOT MASKING TCLP RESULTS

IT IS OUR UNDERSTANDING THAT SINCE THE PUBLICATION OF THE MARCH 2ND FEDERAL REGISTER, EPA HAS ESTABLISHED THAT THE CONCLUSIONS IN THE DATANET REPORT ARE INCORRECT,I.E IRON DOES NOT INTERFERE WITH THE TCLP ANALYSIS FOR LEAD (SEE PHONE MEMOS ON DISCUSSIONS BETWEEN EPA STAFF

AND RMT IN APPENDIX E). BASED ON THIS DETERMINATION, THE ARGUMENT THAT IRON IS MASKING THE TCLP TEST IS UNFOUNDED AND SHOULD 'BE REMOVED FROM DISCUSSION.

BATTELLE REPORT

THE JANUARY, 1994 BATTELLE REPORT RECOGNIZES THAT THERE ARE DATA GAPS AND ISSUES AND PROPOSES SIX EXPERIMENTS TO ANSWER QUESTIONS ON TOPICS INCLUDING: IRON SEGREGATION IN WASTES, ECONOMIC FEASIBILITY, EMPLOYEE SAFETY AND HEALTH, OPTIMAL PROPERTIES OF THE IRON, AND STABILITY OVER TIME. ANOTHER ISSUE IS RAISED BY THE COMMENT ON PAGE 21 OF THE BATTELLE REPORT. "WASTE GENERATED BY REMOVAL OF LEAD PAINT FROM STRUCTURES HAS SOME SIMILARITIES TO SPENT CASTING SAND. BOTH THE CASTING SAND AND ABRASIVE BLASTING MEDIA WASTE ARE A SILICATE MATRIX CONTAINING LEACHABLE LEAD CONTAMINATION. HOWEVER, THE LEAD SPECIES PRESENT AND THE TYPE AND CONDITION OF THE SAND ARE DIFFERENT."

THE ABOVE PROCESSES ARE QUITE DIFFERENT IN CHARACTER. FOUNDRY SAND STABILIZATION IS PERFORMED UNDER CONTROLLED CONDITIONS WITH DISPOSAL PLACEMENT CAREFULLY CONTROLLED. THE ADDED SAND GRAINS AND IRON PARTICLES ARE APPROXIMATELY THE SAME SIZE AND DENSITY, ARE THOROUGHLY BLENDED IN AN ENGINEERED SYSTEM, AND WILL NOT SEPARATE AFTER STABILIZATION. THE PAINT, ON THE OTHER HAND, IS NOT TREATED BUT TAKES ADVANTAGE OF IRON PRESENT DUE TO THE USE OF IRON OR STEEL SHOT TO REMOVE THE PAINT. THIS BLASTING PROCESS IS MUCH LESS CONTROLLED THAN THE FOUNDRY SAND STABILIZATION PROCESS. PAINT FLAKES AND IRON PARTICLES ARE NOT OF THE SAME SIZE AND DENSITY SO MIXING IS LESS EFFECTIVE. THE DIFFERENCES IN LEAD SPECIES IN PAINT AND FOUNDRY PRODUCTS EXPLAIN WHY IRON STABILIZES LEAD BEARING FOUNDRY WASTES, BUT DOES NOT IMMOBILIZE LEAD IN PAINT FLAKES.

IN LIGHT OF THE RECOMMENDATIONS MADE IN THE BATTELLE REPORT AND WITH NO DOCUMENTATION REFERENCED IN THE FEDERAL REGISTER NOTICE THAT SUBSTANTIATES ENVIRONMENTAL HARM DUE TO FOUNDRIES USING THIS STABILIZATION TECHNIQUE, WE QUESTION THE EPA'S DECISION TO MAKE A DETERMINATION THAT IRON ADDITIONS TO FOUNDRY WASTE IS IMPERMISSIBLE DILUTION.

IF EPA FEELS THAT 10% IRON ADDITIONS TO FOUNDRY WASTES IS DILUTION, THEN THEY SHOULD ALSO CONSIDER REEVALUATING OTHER COMMONLY USED TREATMENT TECHNOLOGIES, SUCH AS LIME ADDITIONS, TO DETERMINE IF THE STABILIZATION OBTAINED MIGHT ALSO BE MASKING THE TCLP TEST OR BE DILUTION.

EPA HAS MORE FOUNDRY INFORMATION THAN IS REFERENCED IN MARCH 2, 1995 FEDERAL REGISTER

DURING THE LAST THREE YEARS, EPA HAS REQUESTED AND RECEIVED THOUSANDS OF PAGES OF INFORMATION FROM BRASS FOUNDRIES IN BOTH REGIONS V AND VI REGARDING THEIR USE OF IRON TO STABILIZE LEAD IN FOUNDRY WASTES. THIS INFORMATION INCLUDES LABORATORY ANALYSIS, TREATMENT METHODS AND PROCESSES, QUALITY ASSURANCE PROGRAMS, DAILY RECORDS OF QUANTITIES OF MATERIAL STABILIZED, LANDFILL DATA, GROUND WATER MONITORING DATA AND OPERATIONAL HISTORY. NONE OF THIS INFORMATION IS CITED BY EPA IN THE MARCH 2, 1995 FEDERAL REGISTER.

WE CAN ONLY ASSUME THAT EPA IN WASHINGTON IS EITHER NOT AWARE OF THIS DATA, OR HAS CHOSEN TO IGNORE IT IN THE PROPOSED RULE MAKING. MANY OF THE CRITICAL QUESTIONS RAISED BY BATTELLE IN THEIR JANUARY, 1994 REPORT TO EPA MIGHT HAVE BEEN ANSWERED HAD EPA CHOSEN TO INCLUDE THIS INFORMATION AS PART OF A COMPLETE AND THOROUGH INVESTIGATION ON THE USE OF IRON TO IMMOBILIZE LEAD IN FOUNDRY WASTES.

CASE STUDIES FROM FROUNDRIES PRACTICING IRON TREATMENT OPERATIONS

IN AN ATTEMPT TO ALLEVIATE THIS SITUATION, AFS IS SUBMITTING ACTUAL DATA FROM FOUR FOUNDRIES AS CASE STUDIES. THIS DATA IS INCLUDED IN APPENDICES A-D AND WILL SHOW THE FOLLOWING:

1. IRON ADDED TO LEAD BEARING WASTE FOUNDRY SAND EFFECTIVELY IMMOBILIZES THE LEAD AND YIELDS A PRODUCT THAT CONSISTENTLY PASSES TCLP.

2. THE PROCESS OF MIXING WASTE FOUNDRY SAND WITH IRON IN THE FOUNDRY ENVIRONMENT IS A CONTROLLED PROCESS COMPARABLE TO THE MULLING AND MIXING OF THE SAND IN THE PRODUCTION PROCESS.

3. RECENT TCLP TESTS, RUN ON FOUNDRY SAND THAT WAS TREATED WITH IRON AND LANDFILLED 8-10 YEARS AGO, YIELD LEAD RESULTS BELOW THE 5 PPM LEVEL.

4. GROUNDWATER DATA FROM MONITORING WELLS AT ON-SITE PERMITTED DISPOSAL FACILITIES CONFIRM THAT LEAD LEVELS ARE WELL BELOW FEDERAL DRINKING WATER STANDARDS.

5. MONITORING WELL DATA ALSO SUGGESTS GROUNDWATER IS NOT IMPACTED BY PAST SURFACE IMPOUNDMENTS THAT CONTAINED LEAD BEARING WASTE

FOUNDRY SAND WHICH HAD NOT BEEN TREATED WITH IRON.

6. ANALYSIS FOR TOTAL IRON FROM LANDFILL SAMPLES PROVIDE RESULTS THAT CLEARLY SHOW THE IRON HAS NOT OXIDIZED AFTER SEVERAL YEARS.

THE MATERIAL CONTAINED IN APPENDICES A-D IS BEING SUBMITTED TO CLARIFY ISSUES AND PROVIDE THE DATA SUPPORTING AFS' POSITION FOR EPA REVIEW.

IRON TREATMENT HAS LONG TERM STABILITY

EPA HAS EMPHASIZED THAT IRON TREATMENT IS NOT EFFECTIVE DUE TO THE POTENTIAL FOR OXIDATION OF IRON IN A LANDFILL. THIS WOULD ALLOW THE LEAD TO LEACH OUT OVER TIME. ON PAGE 11731 EPA'S POSITION IS THAT THE STABILIZATION IS TEMPORARY. AFS HAS NOT BEEN ABLE TO FIND DOCUMENTATION TO SUPPORT THE AGENCY'S POSITION. AFS DOES NOT KNOW OF ANY TECHNICAL EVIDENCE SUPPORTING THE EPA'S POSITION AND BELIEVES THAT LONG-TERM STABILITY HAS BEEN DEMONSTRATED. THE FOUNDRY INDUSTRY HAS A DEMONSTRATION OF LONG-TERM EFFECTIVENESS IN THE LANDFILL BASED ON ACTUAL BORINGS AND ANALYSES CONDUCTED UNDER EPA APPROVAL. APPENDIX C CONTAINS A REPORT ENTITLED CHARACTERIZATION OF FOUNDRY WASTE DISPOSED AT THE NACOGDOCHES MUNICIPAL LANDFILL." THE RESULTS DOCUMENT THAT THE IRON TREATED FOUNDRY WASTES PLACED IN THE LANDFILL ARE STILL PROVIDING EFFECTIVE LEAD STABILIZATION AND THE IRON HAS NOT OXIDIZED. THE REPORT CLEARLY INDICATES THAT EFFECTIVE TREATMENT IS IN PLACE AND THAT THE TCLP RESULTS CORRELATE DIRECTLY WITH THE LEVEL OF TOTAL IRON.

TO DATE AFS CONTINUES TO REVIEW DATA RELATIVE TO IRON FILINGS TREATMENT AND HAS ALSO REVIEWED RMT'S RESULTS FROM MULTIPLE EXTRACTION PROCEDURE (MEP). MEP IS THE ONLY MODEL AVAILABLE AND INDICATES EFFECTIVE TREATMENT FOR 1000 YEARS. FIELD STUDIES SUPPORT THE MODEL. WE SIMPLY DO NOT SEE THE JUSTIFICATION FOR THIS RULING. ON WHAT TECHNICAL BASIS IS EPA PROMOTING THIS RULEMAKING AND WHERE ARE THE FACTS?

DISCUSSIONS NEEDED ON THERMAL SAND RECLAMATION

IN THE MARCH 2, 1995 FEDERAL REGISTER, EPA REFERENCES THE FOUNDRY INDUSTRY'S PRACTICE OF RECYCLING FOUNDRY SAND BY THERMALLY OXIDIZING IMPURITIES (PAGE 11731). THIS TECHNOLOGY HAS BEEN FOUND TO BE AN EFFECTIVE POLLUTION PREVENTION MEASURE THAT REDUCES WASTES BY 80% WHILE RETURNING RAW MATERIALS TO THE CASTING PROCESS. LETTERS FROM THE STATES OF CALIFORNIA AND NORTH CAROLINA SPECIFICALLY COMMENDING

FOUNDRIES IN THEIR STATES FOR IMPLEMENTATION OF THIS TECHNOLOGY AND ARE FOUND IN APPENDIX E. OTHER FOUNDRIES ARE PRESENTLY CONSIDERING INSTALLATION OF THIS TECHNOLOGY AS AN INTEGRAL PART OF THEIR SAND SYSTEMS TO REDUCE SOLID WASTES. THERMAL TREATMENT OF FOUNDRY SAND IS A CALCINING OPERATION AND NOT INCINERATION. AS EXPRESSED IN THE GMD COMMENTS, SUBMITTED IN RESPONSE TO THIS PROPOSAL, "THE CALCINING PROCESS DOES NOT CHANGE THE CHEMICAL, BIOLOGICAL, OR PHYSICAL CHARACTER OR COMPOSITION OF THE SAND, I.E. SILICA, SILICON DIOXIDE (SIO2)." GMD'S COMMENTS CLARIFY THE DIFFERENCES BETWEEN THERMAL RECLAMATION OF FOUNDRY SANDS AND HAZARDOUS WASTE INCINERATION AS PRACTICED BY OTHER INDUSTRIES.

//ENDC1

RESPONSE

AFS submitted comments objecting to EPA's position against addition of iron dust to foundry sand. The main points of contention are:

Iron addition to foundry sand is not dilution as EPA categorizes the process, and, the Battelle report recognizes that there are data gaps on issues, and therefore, AFS questions how EPA was able to make the determination that iron dust treatment of foundry sand is impermissible dilution; The commenter pointed out that many data were not cited in the March 2, 1995 Federal Register, and submitted some data of their own;

1. Iron is not masking lead analysis in TCLP results;
2. Lead species are different in the foundry product from that of spent abrasive blasting media, and this difference explains why iron dust treatment works for stabilizing foundry sands;
3. Iron dust treatment of foundry sands provides long-term stability; and
4. Thermal reclamation of foundry sand is an effective pollution prevention measure.

EPA continues to believe that iron dust should be classified as impermissible dilution, as well as a method of treatment that in fact fails to minimize the threats posed by land disposal of D008 wastes. It is unlikely that a chemical reaction occurs when iron dust is added to foundry sands. See, e.g. Kendall Report p. 2. Because the waste foundry sand would likely contain only lead, silica, microscopic pieces of castings, and binders (clays, phenols, and tars) from the molds, EPA is not convinced that the simple addition of iron would provide treatment of the lead or the organics (i.e., phenol and tar). Although it is arguable that iron could form temporary and weak, ionic complexes with silica and/or phenol, so that when analyzed by the TCLP test the lead appears to have been stabilized, EPA believes that this "stabilization" is temporary, based upon the nature of the complexing. In fact, a report by EPA on Iron Chemistry in Lead Contaminated Materials (Feb. 22, 1994), which specifically addressed this issue, found that iron-lead bonds are weak, adsorptive surface bonds. Furthermore, as this iron-rich mixture is exposed to moisture and oxidative conditions over time, interstitial water would likely acidify, which could potentially reverse any temporary stabilization, as well as increase the leachability of the lead from the foundry sand. EPA, therefore believes that the iron-lead bonds are not likely to be permanent.

With respect to the masking issue, the available data indicate that analytical masking (i.e., analytical interference) may not be a problem, as evidenced by the available matrix spike recovery data. EPA has studied the chemistry relative to iron dust treatment which indicates that when the mixture is dry there is no reaction at all. However, once acetic acid is added (during TCLP analysis) some oxidation reduction type chemistry may occur that may mask the lead from getting into solution and hence, not be revealed in analytical analysis. EPA believes that iron treatment masks the TCLP results in that it passes the TCLP test initially but may fail in a longer term. EPA also notes that RCRA requires that the TCLP analysis for determination of TC hazardousness be determined at the point of waste generation.

The Agency acknowledges that there are data gaps with respect to iron dust treatment of foundry sands. To EPA's knowledge, this technology has been in use only since the early 1980's and, thus, there is little data available on long-term effectiveness. The Agency reviewed available data for promulgating this rule including data submitted by commenters that included data from Regions V and VI. The Agency also compiled information on two different studies conducted on this issue, one by Dr. John Drexler of the University of Colorado and the other by Dr. Douglas Kendall of the National Enforcement Investigation Center (NEIC). These studies found that even after treatment, high concentrations of lead remained available to the environment and also leached in fact from spent foundry wastes in actual disposal units. Therefore, these studies concluded that the addition of iron filings or iron dust to lead-contaminated spent foundry sands did not constitute adequate treatment of the waste; there is palpable failure to minimize threats posed by land disposal due to inability to immobilize lead. See the March 5, 1997 NODA (62 FR 10004) for a full discussion of these studies.

The Agency strongly believes that this form of stabilization is only a short-term measure at best, and that it is inadequate to minimize the threats posed by land disposal of metal-containing hazardous wastes. EPA, therefore considers this technology "impermissible dilution" in accordance with 40 CFR 268.3, given the dilutive nature of the phenomenon. Drexler pp. 14, 16, 18. Although the addition of iron dust filings is considered treatment under 260.10, the Agency does not believe it is adequate treatment under section 3004 (m); but merely the addition of material as a substitute for adequate treatment, and therefore constitutes impermissible dilution. See 40 CFR 268.3 (b), 54 FR at 48494 (November 1989), and 55 FR at 22532 (June 1, 1990).

The Agency is also codifying this determination by amending 40 CFR 268.3 to read as follows:

40 CFR 268
§ 268.3 Dilution prohibited as a substitute for treatment

* * *

(d) It is a form of impermissible dilution, and therefore prohibited, to add iron filings or other metallic forms of iron to lead-containing hazardous wastes in order to achieve any land disposal restriction treatment standard for lead. Lead-containing wastes include D008 wastes (wastes exhibiting a characteristic due to the presence of lead), all characteristic wastes containing lead as an underlying hazardous constituent, listed wastes containing lead as a regulated constituent, and hazardous media containing any of the aforementioned lead-containing wastes.

* * *

With respect to the comment on lead species, EPA acknowledges the commenter's point that lead species are different in the foundry product from that of the lead in spent abrasive blasting media. However, EPA does not believe that iron dust treatment of foundry sands is effective for reasons described below. Because the waste foundry sand would likely contain only lead, silica, microscopic pieces of castings, and binders (clays, phenols, and tars) from the molds, EPA is not convinced that the simple addition of iron would provide treatment for the lead or the organics (i.e., phenol and tar). While it may be argued that iron could form temporary and weak, ionic complexes with silica and/or phenol, so that when analyzed by the TCLP test the lead appears to have been stabilized; however, EPA believes that this "stabilization" is temporary, based upon the nature of the complexing. In a report by EPA on Iron Chemistry in Lead Contaminated Materials (Feb. 22, 1994), which specifically addressed this issue, EPA found that iron-lead bonds are weak, adsorptive, surface bonds. EPA believes that these iron-lead bonds are not likely to be permanent. EPA continues to believe that if this iron-rich mixture is exposed to moisture and oxidative conditions over time, interstitial water would likely acidify, which could potentially reverse any temporary stabilization, as well as increase the leachability of the lead from the foundry sand.

The commenter is correct in that the Battelle report did not state that the bonds are not permanent, but concluded that the long-term stability is unknown. However, the Agency remains unconvinced about the long-term stability of this technology. The Agency realizes that this technology has been in use only since the early 1980's and thus, there is little data available on long-term effectiveness. The Agency compiled information on two different studies conducted on this issue, one by Dr. John Drexler of the University of Colorado and the other by Dr. Douglas Kendall of the National Enforcement Investigation Center (NEIC). These studies found that even after treatment, high concentrations of lead remained available to the environment and also leached in the units receiving the spent foundry wastes. Therefore, these studies concluded that the addition of iron filings or iron dust to lead-contaminated spent foundry sands did not constitute adequate treatment of the waste. See the March 5, 1997 NODA (62 FR 10004) for a full discussion of these studies. The conclusions reached by these studies were peer reviewed by an expert panel. The peer reviewers agreed that adding iron filings to spent foundry sand is not treatment of hazardous constituents. The peer reviewers also found that the scientific data presented in the studies support the conclusions reached and the studies are based on sound scientific research and fact. Therefore, the Agency reaffirms its conclusion that the addition of iron filing constitutes impermissible dilution

Regarding the comment on foundry industry's practice of reclaiming foundry sand by thermal oxidization of impurities, the Agency notes that this issue is outside the scope of this rulemaking. This rulemaking only addresses the issues related to the addition of iron filings to spent foundry waste as a method of treatment.

Issue: FOUN1-050 Respondent: TTS

Dcn: PH3P050 Extension: CBI: N
Commenter: STEEL STRUCTURES PAINTING COUNCIL

Comment Number: 00001

//COMM1
//RESPTTS
//SUBJFOUN1-050

BACKGROUND
SSPC HAS IDENTIFIED LEAD PAINT REMOVAL AS A MAJOR ISSUE FOR OUR MEMBERS. OUR ORGANIZATION HAS STRIVED TO IDENTIFY AND ESTABLISH COST EFFECTIVE AND COMPLIANT TECHNIQUES AND STRATEGIES TO REMOVE LEAD PAINT FROM INDUSTRIAL STRUCTURES. IN PARTICULAR, SSPC HAS UNDERTAKEN MAJOR EFFORTS TO EDUCATE OUR MEMBERSHIP ON THE REQUIREMENTS FOR PROPERLY HANDLING AND DISPOSING LEAD BEARING WASTE.

USE OF STEEL GRIT
THE TRADITIONAL MEANS OF REMOVING LEAD PAINT FROM INDUSTRIAL STRUCTURES (E.G. BRIDGES, WATER TOWERS) INCLUDE USE OF NON-METALLIC, EXPENDABLE ABRASIVES SUCH AS SILICA SAND, COAL SLAG AND COPPER SLAG. THE ABRASIVE BLASTING OPERATION CREATES LARGE AMOUNTS OF DUST AND DEBRIS. EVEN WITH ENVIRONMENTAL AND WORKER HEALTH AND SAFETY CONTROLS AS MANDATED BY EPA AND OSHA, IT REMAINS THE MOST PRODUCTIVE AND EFFECTIVE MEANS FOR REMOVING LEAD PAINT. ABRASIVE BLASTING TYPICALLY USES 2-10 POUNDS OF ABRASIVES PER SQUARE FOOT OF SURFACE. WITH SURFACES SPANNING HUNDREDS AND THOUSANDS OF SQUARE FEET, THE AMOUNT OF WASTE IS OFTEN QUITE LARGE. IF THE WASTE IS HAZARDOUS, IT MUST BE TREATED AND DISPOSED, THE COST POTENTIAL OF WHICH IS OFTEN VERY HIGH.

USE OF RECYCLABLE STEEL GRIT
DURING THE PAST 5 TO 10 YEARS MANY OF THE PAINT REMOVAL FIRMS HAVE CONVERTED TO USING RECYCLABLE STEEL ABRASIVES IN PLACE OF EXPENDABLE ABRASIVES. STEEL GRIT AND STEEL SHOT CAN BE RECYCLED 50 OR MORE TIMES,

RESULTING IN A 90%+ REDUCTION OF THE AMOUNT OF WASTE GENERATED. THIS MEETS A KEY RCRA OBJECTIVE OF REDUCING THE AMOUNT OF WASTE PRODUCED. THE MAJOR CHALLENGE IN THE USE OF RECYCLABLE STEEL ABRASIVE IS THE COLLECTION OF THE ABRASIVE AFTER BLASTING AND REMOVING THE PAINT CHIPS AND ABRASIVE FINES FROM THE AFFECTED ABRASIVE. THE INDUSTRY HAS EXPENDED MAJOR RESOURCES IN DEVELOPING IMPROVED TECHNIQUES FOR THESE OPERATIONS. MANY SSPC MEMBERS USE RECYCLABLE STEEL GRIT FOR REMOVING LEAD PAINT FROM INDUSTRIAL STRUCTURES. WE BELIEVE THAT THIS PROCESS IS CONSISTENT WITH THE INTENT AND SPIRIT OF RCRA. NOTE: STEEL ABRASIVE IS, BY NO MEANS, A NEW MATERIAL FOR ABRASIVE BLAST CLEANING. RECYCLABLE STEEL IS COMMONLY USED IN FABRICATING SHOPS TO REMOVE MILL SCALE FROM HOT ROLLED STEEL PRIOR TO APPLYING THE COATING.

SSPC RECOMMENDATIONS
SSPC SUGGEST THE FOLLOWING LANGUAGE FOR A RULE:

WASTE, DEFINED AS SPENT ABRASIVE THAT IS NOT INTENDED FOR RECYCLING, AND MEETING ALL THREE OF THE FOLLOWING REQUIREMENTS, SHALL REQUIRE SPECIAL TREATMENT AS DEFINED BELOW:

1.THE WASTE IS GENERATED DURING BLAST CLEANING REMOVAL OF PAINT USING ABRASIVES WITH 1% BY WEIGHT OR GREATER IRON OR STEEL GRIT OR SHOT;

2.THE WASTE GENERATED WHEN REMOVING PAINT CONTAINING 0.5% BY WEIGHT OR MORE LEAD; AND

3.THE GENERATED WASTE CONTAINS 2% BY WEIGHT OR MORE IRON AS DETERMINED BY AA OR ICP.

WASTE, AS DEFINED ABOVE AND MEETING THE THREE REQUIREMENTS LISTED ABOVE, SHALL REQUIRE A PERMANENT STABILIZATION PROCESS BY AN EPA APPROVED METHOD, SUCH AS TREATMENT WITH PORTLAND CEMENT.

NOTES:
A MINIMUM LEVEL OF 1% IRON OR STEEL GRIT HAS BEEN SELECTED FOR CONDITION 1 FOR THE FOLLOWING REASON: AT TWO PERCENT (2%) ADDITION OF IRON FILINGS TO LEAD WASTE, A NONHAZARDOUS WASTE WAS GENERATED (PRIOR TO THE ADDITION OF THE IRON FILINGS THE WASTE HAD BEEN DETERMINED TO BE HAZARDOUS BY THE TCLP TEST.). HOWEVER, AT 1% ADDITION OF IRON FILINGS, THE WASTE CHARACTERISTIC WAS NOT CHANGED FROM HAZARDOUS TO NONHAZARDOUS. THIS IS BASED ON DATA FROM A FHWA REPORT (FHWA-RD-94-100).
A LEVEL OF 0.5% LEAD-IN-PAINT THRESHOLD HAS BEEN SELECTED BECAUSE THAT

IS THE DEFINITION OF LEAD PAINT BEING USED BY EPA IN THE TITLE X REGULATION (40 CFR 745, PROPOSED 9/2/94).
A LEVEL OF 2% HAS BEEN SELECTED FOR THE LEVEL OF IRON IN PAINT TO ALLOW FOR THE PRESENCE OF IRON OXIDE (E.G. FROM RUST OR IRON OXIDE PIGMENTS IN PAINT). THIS FORM OF IRON WOULD BE PRESENT IN ADDITION TO ANY RESIDUE FROM THE METALLIC ABRASIVE USED FOR BLAST CLEANING.

PROPOSED MODIFICATION TO TCLP
AN ALTERNATIVE SUGGESTED BY SEVERAL OF OUR MEMBERS IS TO MODIFY THE TCLP TEST AS FOLLOWS: MAGNETICALLY REMOVE THE METALLIC IRON PRIOR TO RUNNING THE TCLP TEST. THIS WOULD PREVENT A "MASKING" OF THE TCLP TEST BY THE REACTION BETWEEN METALLIC IRON AND LEAD. IF EPA CONSIDERS THIS A REASONABLE APPROACH, SSPC WOULD MAKE AN EFFORT TO INITIATE A PROTOCOL AND EVALUATION OF SUCH A TREATMENT. NOTE: SSPC LABORATORY PERSONNEL HAVE PERFORMED SOME RELATED WORK WHICH INVOLVED USING MAGNETS TO SEPARATE NON-MAGNETIC IMPURITIES FROM METALLIC ABRASIVES AS PART OF A STANDARD ACCEPTANCE CRITERION.

SSPC BELIEVES THAT A RULE BASED ON THE ABOVE CRITERIA WILL BE PROTECTIVE OF HUMAN HEALTH AND THE ENVIRONMENT AND CONSISTENT WITH EPA"S GOALS. IN ADDITION, IT WILL ENABLE THE PROTECTIVE COATINGS INDUSTRY TO CONTINUE TO USE A PROVEN PROCESS WHICH HAS RESULTED IN SIGNIFICANT REDUCTION IN THE QUANTITY OF LEAD CONTAINING HAZARDOUS WASTE GENERATED. THIS RULE WILL PERMIT THE INDUSTRY TO MEET THE GOALS OF EPA WITHOUT SACRIFICING THE QUALITY, PRODUCTIVITY AND COST EFFECTIVENESS OF THIS METHOD OF LEAD PAINT REMOVAL.

//ENDC1

RESPONSE

The Steel Structures Painting Council suggested the Agency propose specific language (supplied by the commenter) as a rule for spent abrasive waste generated from lead paint removal operations.

The Agency disagrees with the commenter's suggestion to specify compositions and criteria of the as generated waste. EPA maintains that if the waste meets the definition of a toxicity characteristic hazardous waste, then it will be subject to the land disposal restrictions for the particular characteristic waste (e.g., lead-D008). The commenter's suggestion would be tantamount to "listing" a waste, and as such is beyond the scope of this land disposal restrictions rule. Further, th suggestion to require a specific disposal method such as a permanent stabilization technology for these spent abrasive wastes will preclude the use of other applicable and demonstrated technologies, and hence, not provide treaters with maximum flexibility for selection of treatment./disposal options.

EPA wishes to note that, should the commenter believe that their waste is unique to the extent that the current treatment standards for characteristic waste is in appropriate, then they may petition the Agency for a treatability variance as per 40 CFR 268.44 on a case-by-case basis.

EPA disagrees with the commenter's suggestion that EPA modify the TCLP analysis with respect to these wastes whereby metallic iron could be magnetically removed prior to running the TCLP test. The Agency notes that RCRA requires that the TCLP analysis for determination of TC hazardousness be performed at the point of waste generation (55 FR 11830, March 29, 1990). The modification the commenter suggests would result in treatment prior to analysis for TC hazardousness.

Issue: FOUN1-051 Respondent: TTS

Dcn: PH3P051 Extension: CBI: N
Commenter: RMT, INC

Comment Number: 00001

//COMM1
//RESPTTS
//SUBJFOUN1-051

RMT"S RESPONSE

FIRST, TREATMENT OF BRASS FOUNDRY SAND WITH IRON TO IMMOBILIZE LEAD IS NOT DILUTION IN THE STANDARD USE OF THE TERM. TREATMENT TYPICALLY INVOLVES THE ADDITION OF BETWEEN 1 AND 10 PERCENT METALLIC IRON. LEAD CONCENTRATIONS IN THE TCLP TEST ARE REDUCED FROM HUNDREDS OF MILLIGRAMS PER LITER (MG/L) TO LESS THAN 1 MG/L. THERE IS A CHEMICAL REACTION OCCURRING WITH THE ADDITION OF THE IRON OTHERWISE THE ADDITION OF 10% OF AN ADDITIVE COULD NOT REDUCE THE LEAD CONCENTRATION BY A FACTOR OF OVER 100 DUE TO DILUTION ALONE. THE IRON CLEARLY REACTS VERY STRONGLY WITH THE LEAD FOR SUCH A SMALL DOSAGE TO REDUCE THE CONCENTRATION BY SUCH A LARGE FACTOR. METALLIC IRON IS MORE EFFECTIVE AT STABILIZING LEAD THAN MOST OTHER TREATMENT ADDITIVES INCLUDING THE ADDITIVES MOST COMMONLY USED AS STABILIZATION/SOLIDIFICATION AGENTS, SUCH AS LIME OR CEMENT. UNDERSTANDING THE CHEMISTRY OF THE REACTION BETWEEN THE LEAD AND IRON BECOMES KEY TO DISCUSSING WHETHER THE TREATMENT PROCESS IS A VIABLE STABILIZATION OR IS SIMPLY "MASKING" THE LEAD IN THE TCLP TEST. IF IT IS SIMPLY MASKING THE LEAD WITHOUT A REAL STABILIZATION OCCURRING, WHICH WOULD PROTECT LEAD FROM LEACHING IN THE REAL WORLD, IT WOULD BE CONSIDERED AN "IMPERMISSIBLE DILUTION" UNDER THE EPA"S DEFINITION.

A. METALLIC IRON DOES NOT REACT WITH LEAD; THEREFORE, IT IS AN IMPERMISSIBLE DILUTION.

THE EPA"S POSITION STATED IN THE FEDERAL REGISTER IS THAT "IRON COULD

FORM TEMPORARY, WEAK, IONIC COMPLEXES WITH SILICA AND/OR PHENATE, SO THAT WHEN ANALYZED BY THE TCLP TEST THE LEAD APPEARS TO HAVE BEEN STABILIZED, THE AGENCY BELIEVES THIS "STABILIZATION" IS TEMPORARY, BASED UPON THE NATURE OF THE COMPLEXING. IN FACT, A REPORT PREPARED BY THE EPA IN IRON CHEMISTRY OF LEAD CONTAMINATED MATERIALS (FEB 22, 1994), WHICH SPECIFICALLY ADDRESSED THIS ISSUE, FOUND THAT IRON-LEAD BONDS ARE WEAK, ADSORPTIVE SURFACE BONDS, AND THEREFORE NOT LIKELY TO BE PERMANENT."

FIRST, THE EPA"S STATEMENT QUOTED ABOVE MAKES NO TECHNICAL SENSE WITHOUT FURTHER EXPLANATION. EVEN ASSUMING THAT IRON DOES FORM WEAK COMPLEXES WITH SILICA OR PHENOL, WHAT INFLUENCE DOES SUCH A REACTION HAVE ON THE LEACHING BEHAVIOR OF LEAD IN A TCLP TEST? IS LEAD SUPPOSEDLY TRAPPED IN THE COMPLEX? IF SO, HOW CAN SO WEAK A COMPLEX SO STRONGLY IMMOBILIZE LEAD IN A TCLP TEST? THE RELATIONSHIP OF THE WEAK COMPLEX BETWEEN IRON AND SILICA OR PHENOL AND LEAD LEACHING IS NOT EXPLAINED.

MOREOVER, THE EPA"S POSITION IS NOT SUPPORTED BY THE BACKGROUND REPORT CITED IN THE FEDERAL REGISTER. THE REPORT MENTIONED IS A COVER MEMO ON A REPORT BY THE COLUMBUS, OHIO, OFFICE OF BATTELLE INC. TITLED "SUMMARY OF DATA ANALYSIS AND EXPERIMENTAL DESIGN FOR INVESTIGATION OF IRON CHEMISTRY IN LEAD CONTAMINATED MATERIALS (JANUARY, 1994)." THERE IS NO MENTION OF A REACTION BETWEEN IRON AND SILICA OR PHENOL IN THE BATTELLE REPORT. THE BATTELLE STUDY INCLUDES A LITERATURE REVIEW AND THERMODYNAMIC MODELING OF THE REACTION BETWEEN IRON AND LEAD IN BRASS FOUNDRY SAND TREATMENT. THERE ARE NO NEW DATA PRESENTED IN THE BATTELLE REPORT. THE STUDY FINDS THAT THERE ARE TWO REACTION MECHANISMS THAT MAY IMMOBILIZE LEAD: AN OXIDATION-REDUCTION REACTION BETWEEN METALLIC IRON AND DISSOLVED LEAD, AND AN ADSORPTION REACTION BETWEEN FERRIC HYDROXIDE (OR MORE TECHNICALLY HYDROUS FERRIC OXIDE) AND DISSOLVED LEAD. SINCE METALLIC IRON IS ADDED DURING THE TREATMENT PROCESS, IT IS CLEARLY THE REDOX REACTION THAT IS IMMOBILIZING LEAD DURING THE TCLP TEST. THIS SAME CONCLUSION HAS BEEN FOUND BY ALL OF THE OTHERS WHO HAVE INVESTIGATED THE REACTION (NAGEL, ET AL., 1983; STEPHENS, ET AL., 1984; OSTROM AND TROJAN, 1988; SMITH, ET AL., 1991). THE REACTION BETWEEN HYDROUS FERRIC OXIDES AND LEAD HAS BEEN FOUND TO BE EFFECTIVE IN SOME CASES (OSTROM AND TROJAN, 1988) BUT NOT IN OTHERS (OSTROM ET AL., 1985). THE REACTION MECHANISM FOR THE STABILIZATION REACTION IS THEREFORE A REDOX REACTION, IN WHICH THE METALLIC IRON REDUCES DIVALENT LEAD TO THE METALLIC FORM AND IS ITSELF OXIDIZED, I.E.

$$FEO + PB2+ = FE2+ + PBO$$

THE REACTION BETWEEN METALLIC IRON AND DISSOLVED METALS IS WELL KNOWN. THERE IS A WASTEWATER TREATMENT PROCESS, IRON CEMENTATION, THAT USES METALLIC IRON TO REMOVE HEAVY METALS (E.G. COPPER, LEAD) FROM A WASTEWATER (AGELIDIS, ET AL., 1988; KU AND CHEN, 1992). IN ADDITION, STANDARD INTRODUCTORY CHEMICAL TEXTBOOKS DISCUSS THE OXIDATION-REDUCTION (REDOX) REACTION BETWEEN IRON AND OTHER METALS (E.G., SIENKO AND PLANE, 1966). THIS REDOX REACTION WOULD OCCUR IN A LANDFILL IN THE PRESENCE OF IRON IF LEAD WERE SOLUBILIZED FROM THE WASTE MATERIAL, AND IT OCCURS IN THE TCLP TEST.

THE EPA"S SUGGESTION THAT IRON FORMS "TEMPORARY, WEAK, IONIC COMPLEXES WITH SILICA AND/OR PHENATE" INDICATES THAT THEY DO NOT UNDERSTAND THE REACTION CHEMISTRY THAT HAS BEEN PRESENTED IN THE DOCUMENT THAT THEY CITE AS SUPPORTING THEIR POSITION. THE EPA"S POSITION THAT THERE IS NO REACTION BETWEEN IRON AND LEAD IS CONTRADICTED BY THEIR OWN REFERENCE, AS WELL AS BY THE OTHER RESEARCHERS ON THE SUBJECT. A SEPARATE QUESTION IS APPROPRIATE AS TO THE LONG-TERM EFFECTIVENESS OF IRON TREATMENT, BUT TO CLAIM THE REACTION DOES NOT OCCUR IS SIMPLY INCORRECT.

B. ACID FORMATION IN LANDFILLS

THE EPA"S SECOND REASON FOR PROPOSING TO BAN THE USE OF METALLIC IRON IS THAT THE IRON MAY GENERATE ACID CONDITIONS IN A LANDFILL. HOWEVER, THE EPA GIVES NO SUPPORTING DOCUMENTATION FOR THIS ASSERTION. THERE IS NO OBVIOUS BASIS FOR THE ASSERTION, AND IT IS CONTRARY TO EXPERIENCE THAT METALLIC IRON WILL GENERATE ACID CONDITIONS.

ACIDIC CONDITIONS CAN BE GENERATED FROM SOME FORMS OF IRON, PARTICULARLY FROM THE OXIDATION OF FERROUS SULFIDE (PYRITE) AS OCCURS IN ACID MINE DRAINAGE, OR FROM THE HYDROLYSIS OF FERRIC IRON TO FORM FERRIC HYDROXIDE AS OCCURS DURING WASTEWATER TREATMENT WITH FERRIC SALTS. NEITHER OF THESE SITUATIONS OCCURS IN THE SCENARIO WHEN METALLIC IRON IS USED FOR TREATING BRASS FOUNDRY WASTES. METALLIC IRON, IN FACT, WILL REACT WITH ACIDS TO GENERATE HYDROGEN GAS, AND IN THE PROCESS, WILL NEUTRALIZE THE ACID, I.E.

$$FEO + 2 H+ = FE2+ + H2$$

THE EVOLUTION OF HYDROGEN GAS WHEN METALS ARE ADDED TO AN ACIDIC SOLUTION IS A WELL-KNOWN PHENOMENON. AS AN EXAMPLE, IRON USED TO TREAT FOUNDRY WASTES WILL FREQUENTLY NEUTRALIZE THE ACETIC ACID USED IN THE TCLP TEST AND RAISE THE PH ABOVE 5. FOR THE EPA TO SUGGEST THAT METALLIC IRON WILL GENERATE ACIDS IS SIMPLY CONTRARY TO EXPERIENCE AND BASIC CHEMISTRY.

FURTHERMORE, IF METALLIC IRON IN THE ENVIRONMENT GENERATED ACIDS, THEN ONE WOULD EXPECT TO FIND ACIDIC LEACHATES ARISING FROM SITUATIONS WHERE METALLIC IRON OCCURRED OR WAS DISPOSED IN THE ENVIRONMENT. IRON FOUNDRY LANDFILLS OFTEN CONTAIN SIGNIFICANT AMOUNTS OF METALLIC IRON, EITHER IN THE FORM OF METAL GRINDING WASTES OR AS WASTE FROM THE MELTING AND CASTING PROCESS. THESE LANDFILLS DO NOT BECOME ACIDIC OVER TIME, NOR DO THE WASTES APPEAR TO CONTRIBUTE HYDROGEN ION TO THE GROUNDWATER (HAM, ET AL., 1985). IF METALLIC IRON IN LANDFILLS GENERATED ACIDIC CONDITIONS, THEN ONE WOULD EXPECT THAT THE MANY IRON FOUNDRY LANDFILLS THROUGHOUT THE COUNTRY WOULD BE EXPERIENCING ENVIRONMENTAL PROBLEMS DUE TO ACID GENERATION. THIS IS SIMPLY NOT THE CASE.

ONE OF THE MORE INTERESTING APPLICATIONS OF METALLIC IRON FOR ADDRESSING ENVIRONMENTAL PROBLEMS IS IN THE USE OF REACTION WALLS BUILT INTO THE SOIL FOR THE DEHALOGENATION OF CHLORINATED SOLVENTS IN GROUNDWATER. AT A SYMPOSIUM ENTITLED "CONTAMINANT REMEDIATION WITH ZERO-VALENT METALS" HELD AT THE 209TH AMERICAN CHEMICAL SOCIETY"S NATIONAL MEETING IN ANAHEIM, CALIFORNIA (APRIL 2-7, 1995), THIRTY-THREE PAPERS WERE PRESENTED ON THE USE OF METALLIC IRON FOR THE DESTRUCTION OF ORGANIC COMPOUNDS. IF METALLIC IRON GENERATED ACID IN SUBSURFACE CONDITIONS, THEN SURELY THE ISSUE WOULD BE OF MAJOR CONCERN IN THESE PAPERS. IF THE ACID GENERATION POTENTIAL FROM METALLIC IRON USED TO TREAT FOUNDRY WASTES IS OF SUFFICIENT CONCERN TO BAN THE PROCESS, THEN THE POSSIBILITY OF ACID GENERATION FROM THE METALLIC IRON REACTION WALLS WOULD BE EXPECTED TO BE OF SUFFICIENT CONCERN FOR THIS PROCESS. HOWEVER, THE POSSIBILITY OF ACID FORMATION FROM THE USE OF IRON WAS NOT MENTIONED IN THE ABSTRACTS.

AGAIN, THE EPA IN THEIR PRESENTATION IN THE FEDERAL REGISTER DOES NOT UNDERSTAND THE CHEMISTRY OF IRON IN FOUNDRY WASTES, AND MISREPRESENTS THE ACTUAL REACTIONS.

C. IRON INTERFERES WITH LEAD ANALYSIS IN TCLP TEST LEACHATES, THEREBY GENERATING FALSE NEGATIVES

THE EPA ASSERTS THAT METALLIC IRON INTERFERES WITH THE ANALYSIS OF IRON IN TCLP TEST LEACHATES. THE CITATION IN THE FEDERAL REGISTER IS A LETTER FROM JOHN CIGNATTA, OF DATANET, TO JOHN GAUTHIER OF REGION I, EPA. THE LETTER CITES MS. GAIL HANSEN, OF THE EPA OFFICE OF SOLID WASTE, FOR THE ASSERTION THAT METALLIC IRON INTERFERES WITH THE ANALYSIS OF LEAD IN TCLP TEST LEACHATES. MR. CIGNATTA STATES THAT "ACCORDING TO MS. GAIL HANSEN OF EPA OFFICE OF SOLID WASTE, THE PRESENCE OF IRON MAKES THE TCLP TEST QUITE IMPRACTICAL AS ESTABLISHED BY SPIKED SAMPLES HAVING EXCEEDINGLY POOR RECOVERY RATES." WHEN FIRST ASKED ABOUT MR. CIGNATTA"S STATEMENT, MS. HANSEN SAID THAT SHE DID NOT RECALL MAKING THIS STATEMENT. UPON SEVERAL DAYS REFLECTION, HOWEVER, MS. HANSEN VAGUELY RECALLED A REPORT BY AN OUTSIDE LABORATORY THAT MAY HAVE INDICATED AN ANALYTICAL INTEREFERENCE BETWEEN IRON AND LEAD. SHE COULD NOT LOCATE THE REPORT, AND DOES NOT RECALL SPECIFICALLY WHAT LABORATORY WROTE THE REPORT, OR THE DETAILS OF THE INTEREFERENCE. SINCE THE REPORT IS NOT AVAILABLE FOR REVIEW, IT IS DIFFICULT TO DETERMINE ON WHAT BASIS THE CLAIM WAS MADE AS TO THE INTEREFERENCE. OLLIE FORDHAM, NATIONAL PROGRAM MANAGER FOR INORGANIC SW846 ANALYSIS, STATED THAT THERE IS NO ANALYTICAL INTEREFERENCE IN THE AA OR ICP ANALYSIS BETWEEN IRON AND LEAD AFTER THE TCLP TEST LEACHATE IS FILTERED UNLESS THE IRON IS PRESENT IN HIGH CONCENTRATIONS (ABOVE A THOUSANDS MG/L). AS A PRACTICAL MATTER, IF IRON DID INTEREFERE WITH THE ANALYSIS OF LEAD IN TCLP TEST LEACHATES, THEN EVERY LABORATORY IN THE COUNTRY THAT RUNS IRON-TREATED MATERIALS SHOULD BE REPORTING THE FACT, SINCE SPIKING TCLP TEST LEACHATES IS PART OF THE STANDARD QC PROTOCOL FOR TCLP TEST. AS ONE EXAMPLE, THE RMT LABORATORY DOES NOT HAVE ANY DIFFICULTY IN OBTAINING EXCELLENT SPIKE RECOVERIES FROM TCLP TEST LEACHATES OF IRON TREATED WASTES. SINCE THERE IS NO DOCUMENTATION OF A PROBLEM IN THE ANALYSIS OF LEAD IN TCLP LEACHATES FROM IRON TREATED WASTES, AND SINCE THE RMT LABORATORY HAS NEVER ENCOUNTERED ANY DIFFICULTIES, OUR CONCLUSION IS THAT THERE IS NO PROBLEM WITH THE ANALYSIS.

IN SUMMARY, ALL OF THE TECHNICAL ARGUMENTS THAT THE EPA PRESENTS FOR JUSTIFYING BANNING THE USE OF METALLIC IRON ARE NOT TRUE AND ARE NOT SUPPORTED BY THE BACKGROUND DOCUMENTATION PRESENTED BY THE EPA.

OTHER CONCERNS ABOUT IRON TREATMENT

THERE ARE CONCERNS THAT ARE IMPLIED BUT NOT DIRECTLY STATED BY THE EPA ABOUT THE USE OF METALLIC IRON FOR TREATING WASTES. THESE ISSUES HAVE BEEN RAISED AT LEAST IN PART BY SOME OF THE AUTHORS WHO DISCUSS IRON TREATMENT, PARTICULARLY SMITH ET AL.(1991). THE CONCERNS ABOUT IRON

TREATMENT ARE TWOFOLD, AS FOLLOWS:

NO REACTION OCCURS WHEN IRON IS ADDED TO WASTE, AND THE TREATMENT IS THUS "MASKING" LEAD IN THE TCLP TEST. FURTHERMORE, THE ADDITIVE AND WASTE COULD SEPARATE DURING TRANSPORT.

FIRST, THERE IS NO REACTION BETWEEN LEAD AND ANY DRY ADDITIVE, BE IT LIME, CKD, PORTLAND CEMENT, OR METALLIC IRON. THE REACTIONS DO NOT OCCUR UNTIL THE SAMPLE GETS WET. THE ARGUMENT THAT IRON IS NOT EFFECTIVE COULD EQUALLY WELL BE APPLIED TO ANY DRY ADDITIVE. LEAD WILL NOT LEACH FROM THE WASTE UNTIL THE WASTE GETS WET, SO THAT THE CONCERN ABOUT NO REACTION OCCURRING UNTIL THE SAMPLE IS WETTED IS IRRELEVANT, PROVIDED THAT THE WASTE AND ADDITIVE DO NOT SEPARATE PRIOR TO WETTING.

IT IS UP TO THE GENERATOR TO ENSURE GOOD MIXING BETWEEN THE WASTE AND ADDITIVE, NO MATTER WHAT TYPE OF ADDITIVE IS USED. THE EPA SHOULD NOT BAN A PROCESS BECAUSE THEY ARE CONCERNED ABOUT MIXING EFFECTIVENESS.

IRON MAY OXIDIZE IN A LANDFILL AND THUS NOT PROVIDE REAL LONG-TERM TREATMENT

THE CONCERN THAT IRON USED FOR TREATMENT WILL OXIDIZE AFTER DISPOSAL AND THEREFORE NOT PROVIDE LONG-TERM TREATMENT FOR THE WASTE, WILL NOT OCCUR FOR A BRASS FOUNDRY WASTE. IN ORDER TO OXIDIZE THE IRON, AN OXIDIZING AGENT IS REQUIRED. SINCE THE IRON CONSTITUTES ABOUT 10 PERCENT OF THE WASTE, THE OXIDIZING AGENT HAS TO BE PRESENT AT A SUFFICIENT CONCENTRATION TO OXIDIZE THE LARGE AMOUNT OF IRON. THE MOST COMMON OXIDIZING AGENT IS, OF COURSE, ATMOSPHERIC OXYGEN. HOWEVER, THE WASTE IS EFFECTIVELY ISOLATED FROM THE AIR WHEN IT IS PLACED IN A LANDFILL. IN ORDER TO MOVE SUFFICIENT OXYGEN INTO THE LANDFILL TO OXIDIZE THE IRON, SEVERAL HUNDRED PORE VOLUMES OF AIR WOULD BE REQUIRED TO PASS THROUGH THE WASTE. SINCE THERE IS NO MAJOR DRIVING FORCE FOR THE AIR TO MOVE IN OR OUT OF THE LANDFILL, THE LARGE VOLUMES OF AIR REQUIRED TO OXIDIZE THE IRON WILL NOT PASS THROUGH THE LANDFILL. THE METALLIC IRON ESTABLISHES AND MAINTAINS ANOXIC CONDITIONS IN THE LANDFILL.

MODELING LONG-TERM LEACHING

THE EPA HAS ESTABLISHED THE MULTIPLE EXTRACTION PROCEDURE (MEP) (SW846 METHOD 131) TO MODEL THE LONG-TERM LEACHING POTENTIAL OF WASTES. IF IRON-TREATED WASTES WERE NOT STABLE, THEN THE TREATED WASTES SHOULD

NOT BE STABLE IN AN MEP TEST. HOWEVER, SUCH IS NOT THE CASE. THE RESULTS OF AN MEP TEST CONDUCTED ON AN IRON-TREATED BRASS FOUNDRY SAND ARE PRESENTED IN TABLE 1. THE TEST WAS CONDUCTED AS PART OF A SUBMITTAL TO REGION V OF THE EPA, AND WAS ACCOMPANIED BY THE FULL QC PACKAGE. AS CAN BE SEEN, THE IRON-TREATED WASTE DID NOT LEACH LEAD ABOVE THE DETECTION LIMIT IN ANY OF THE TEN ELUTIONS. IF IRON WERE EASILY OXIDIZED, THEN ONE WOULD EXPECT IT TO BE OXIDIZED IN THE MEP TEST, AND ONE WOULD LIKEWISE EXPECT THE TEST RESULTS TO DEMONSTRATE THE FAILURE OF THE TREATMENT.

FURTHERMORE, CASE STUDIES ON BRASS FOUNDRY LANDFILLS IN WHICH IRON TREATMENT HAS BEEN EMPLOYED HAVE NOT SHOWN PROBLEMS DUE TO OXIDATION OF THE IRON. THESE CASE STUDIES ARE PRESENTED IN THE SUBMITTAL FROM THE AMERICAN FOUNDRYMENS SOCIETY ON THE SAME ISSUE.

THUS, THERE IS NO EVIDENCE, EITHER FROM LEACHING TESTS OR FROM REAL-WORLD EXPERIENCE, THAT IRON TREATMENT IS NOT A SUCCESSFUL LONG-TERM TREATMENT FOR BRASS FOUNDRY SAND, WHEN THE TREATMENT IS CONDUCTED IN AN APPROPRIATE MANNER.

IRON VS. LIME TREATMENT

TREATMENT WITH METALLIC IRON PARALLELS IN MANY ASPECTS TREATMENT WITH A LIME-BASED ADDITIVE, SUCH AS LIME ITSELF OR CEMENT KILN DUST (CKD) BOTH COMMONLY USED TREATMENT ADDITIVES. WHILE IRON REACTS WITH LEAD TO FORM LEAD METAL, LIME SIMPLY MAINTAINS THE PH OF THE LEACHING TESTS IN A REGION WHERE LEAD OXIDE/HYDROXIDE IS NOT SOLUBLE. LIME OR A LIME-BASED ADDITIVE DOES NOT REACT DIRECTLY WITH THE LEAD IN THE WASTE TO FORM AN INSOLUBLE PRECIPITATE. (THE ARGUMENT THAT LIME CONVERTS THE LEAD TO A LEAD OXIDE OR HYDROXIDE IS NOT RELEVANT, SINCE BOTH COMPOUNDS ARE QUITE SOLUBLE AT PH 5, THE NOMINAL PH OF THE TCLP TEST AND SO IF THE PH OF THE TCLP TEST WERE NOT RAISED BY THE LIME TO A RANGE WHERE LEAD IS NOT SOLUBLE, THE WASTE WOULD STILL BE HAZARDOUS. IN ADDITION, LEAD IN THE ENVIRONMENT WILL CONVERT TO AN OXIDE OR HYDROXIDE IF IT EXISTS IN A MORE SOLUBLE FORM TO START WITH. THEREFORE TO STATE THAT LIME "CONVERTS" THE LEAD TO AN OXIDE FORM IS NOT TECHNICALLY CORRECT.) IN THE SAME MANNER THAT CONCERNS CAN BE RAISED ABOUT IRON OXIDIZING, LIME MAY BE LEACHED OUT A WASTE, LEAVING BEHIND AN "UNTREATED" WASTE THAT WOULD FAIL A TCLP TEST IF THE WASTE WERE RETESTED.

ACTUALLY, IRON TREATMENT MAY BE SUPERIOR TO LIME TREATMENT. LIME IS A VERY CAUSTIC MATERIAL, AND DURING TREATMENT WILL RAISE THE PH OF THE

TREATED MATERIAL TO ROUND 12.5 THE TCLP TEST USES A STRONGLY BUFFERED ACID SOLUTION (0.1M ACETATE). SUCH HIGH BUFFERING CAPACITY IS NOT NORMALLY ENCOUNTERED IN FOUNDRY WASTE LANDFILLS, SINCE THERE IS NO DEGRADING ORGANIC MATTER TO GENERATE THE VOLATILE ORGANIC ACIDS. RATHER THE LEACHING SOLUTION IN FOUNDRY WASTE LANDFILLS IS LIKELY TO BE SIMILAR TO THE SYNTHETIC ACID RAIN USED IN THE SYNTHETIC PRECIPITATION LEACHING PROCEDURE (SPLP - SW 846 METHOD 1312). IF SUFFICIENT LIME IS ADDED TO A WASTE TO NEUTRALIZE THE ACID IN THE TCLP TEST AND BRING THE PH TO THE RANGE WHERE LEAD IS NOT SOLUBLE IN THE TCLP TEST LEACHATE, THEN THE LIME WILL RAISE THE PH OF AN SPLP TEST LEACHATE TO AROUND 12.5 (THE PH OF A LIME-SATURATED SOLUTION). LEAD IS AN AMPHOTERIC METAL, AND IS SOLUBLE UNDER BOTH ACIDIC AND BASIC PH CONDITIONS. AT A PH OF 12.5, DISSOLVED LEAD CONCENTRATION IN SOLUTION CAN REACH TENS OF MG/L. THE USE OF LIME TO REDUCE LEACHING IN A TCLP TEST MAY RESULT IN THE TREATED WASTE LEACHING HIGH CONCENTRATIONS OF LEAD IN AN SPLP TEST, OR IN THE NATURAL ENVIRONMENT. IRON TREATMENT, ON THE OTHER HAND, HAS NO SUCH CONCERNS. LEAD IS NOT "AMPHOTERIC" ON A REDOX SCALE--IT DOES NOT GO BACK INTO SOLUTION AS THE REDOX POTENTIAL IS LOWERED PAST A CERTAIN POINT.

A DEMONSTRATION OF THIS DIFFERENCE IS GIVEN IN TABLE 2. SPLP TESTS WERE RUN ON A SAMPLE OF BRASS FOUNDRY SAND TREATED WITH BOTH METALLIC IRON (60%) AND LIME (6%). THE UNTREATED FOUNDRY SAND LEACHED LEAD AT 400 MG/L IN A TCLP TEST. IN AN SPLP TEST ON THE TREATED WASTE SAMPLES, THE IRON-TREATED WASTE GAVE A LEAD CONCENTRATION IN THE SPLP LEACHATE OF < 0.003 MG/L, WHILE THE LIME-TREATED WASTE GENERATED A LEAD CONCENTRATION OF 23 MG/L. THE LIME HAS RAISED THE PH OF THE SPLP TEST LEACHATE TO THE POINT WHERE LEAD IS RESOLUBILIZED, WHILE THE IRON EFFECTIVELY STABILIZES THE LEAD IN THE WASTE TO VERY LOW LEVELS DURING THE TEST. IRON TREATMENT IS CLEARLY SUPERIOR TO LIME TREATMENT FOR THIS WASTE (A TYPICAL BRASS FOUNDRY SAND).

TO FURTHER DEMONSTRATE THE COMPARISON BETWEEN LIME AND IRON, MEP LEACHING TESTS WERE CONDUCTED ON THE SAMPLE OF BRASS FOUNDRY SAND TREATED WITH BOTH IRON (10% DOSE) AND LIME (6% DOSE). THIS TESTING IS STILL UNDERWAY, AND THE COMPLETE RESULTS WILL BE PROVIDED TO EPA.

APPROPRIATE LEACHING TEST FOR FOUNDRY WASTES GOING TO A MONOFILL IS THE SPLP TEST

THE EPA REQUESTED THAT SUBMITTERS RECOMMEND A MORE APPROPRIATE LEACHING TEST FOR BRASS FOUNDRY SAND THAN THE TCLP TEST. WE RECOMMEND THAT THE SPLP TEST BE USED FOR EVALUATING THE LEACHING

POTENTIAL OF FOUNDRY WASTES GOING TO NON-MUNICIPAL ONLY LANDFILLS, INCLUDING FOUNDRY WASTE■ONLY LANDFILLS. THE ACETIC ACID USED IN THE TCLP TEST MODELS THE ACID GENERATED DURING THE FACULTATIVE DECOMPOSITION STAGE OF A MUNICIPAL LANDFILL. LEACHATES FROM THIS STAGE OF THE LANDFILL DECOMPOSITION MAY CONTAIN HIGH CONCENTRATIONS OF VOLATILE ORGANIC ACIDS, SUCH AS ACETIC ACID, FROM THE DECOMPOSITION OF ORGANIC MATERIALS PLACED IN THE LANDFILL. HOWEVER, FOUNDRY WASTE■ONLY LANDFILLS DO NOT CONTAIN LARGE AMOUNTS OF PUTRESCIBLE ORGANIC MATTER, AND THEREFORE DO NOT GENERATE LEACHATES WITH HIGH CONCENTRATIONS OF VOLATILE ORGANIC ACIDS. FOUNDRY WASTE LANDFILLS TEND TO HAVE BASIC RATHER THAN ACIDIC PH VALUES (HAM, ET AL.). THEREFORE, A TEST THAT USES A HIGHLY ORGANIC ACID LEACHING SOLUTION DOES NOT PROVIDE A REALISTIC EVALUATION OF THE LEACHING ENVIRONMENT OF A FOUNDRY WASTE LANDFILL, OR OF MANY OTHER WASTE DISPOSAL CONDITIONS EITHER. THE SPLP TEST USES A SYNTHETIC ACID RAIN AS A LEACHING MEDIUM, AND PROVIDES A LEACHING SOLUTION THAT IS FAR MORE REALISTIC THAN THE ACETIC ACID USED IN THE TCLP TEST. AS DISCUSSED ABOVE FOR THE COMPARISON BETWEEN LIME AND IRON TREATMENT, THERE MAY BE SITUATIONS WHERE A WASTE TREATMENT PROCESS EFFECTIVELY IMMOBILIZES LEAD IN THE TCLP TEST, BUT INCREASES THE LEACHING POTENTIAL OF LEAD IN THE MORE REALISTIC SPLP TEST (E.G., LIME TREATMENT). SUCH A TREATMENT PROCESS SOLVES A REGULATORY PROBLEM, BUT MAY CREATE A REAL ENVIRONMENTAL PROBLEM. USE OF THE SPLP TEST FOR EVALUATING THE LEACHING POTENTIAL OF WASTES IN FOUNDRY WASTE-ONLY LANDFILLS WOULD PROVIDE A MUCH MORE REALISTIC VIEW OF THE LEACHING POTENTIAL OF THE WASTE. USE OF THE SPLP TEST, OR A SIMILAR WATER LEACHING TEST HAS BEEN PROPOSED BY OTHERS (HAM, ET AL., 1979). WE WOULD STRONGLY SUPPORT THE USE OF THE SPLP TEST AS AN ALTERNATIVE OR A COMPLEMENT TO THE TCLP TEST FOR EVALUATING THE LEACHING POTENTIAL OF FOUNDRY WASTES.

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RESPONSE

RMT, Inc., submitted comments objecting to EPA's position against addition of iron dust to foundry sand. The main points raised by RMT, Inc. were:

1. Iron addition to foundry sand is not dilution as EPA categorizes the process;
2. Iron addition to foundry sand will not create acidic conditions in landfills;
3. Iron addition to foundry sand will not mask lead analysis in TCLP testing;
4. The iron added to the foundry sand will not separate out during transport;
5. Landfill conditions will not allow the iron to oxidize to the extent that long-term stability will

be adversely impacted;

6. Iron treatment is more effective at treating the foundry sands than pozzolonic treatment; and
7. The SPLP leach test is a more appropriate test than TCLP for foundry wastes going into a monofill.

The Agency's determination that the addition of iron filing constitutes impermissible dilution is predicated on the fact that the adsorption of soluble lead on to the iron surface is a reversible reaction and once the iron surfaces oxidize, the ability of the additive to scavenge soluble metals is diminished. Therefore, the treatment is not permanent. In addition, adsorption alone is not a reliable method of permanently immobilizing lead. The longevity of treatment cannot be measured by the TCLP test, which provides only a snapshot of the leachable constituents under the test condition at the time of analysis.

The commenter is correct in that the Battelle report did not state that the bonds are not permanent, but concluded that the long-term stability is unknown. However, the Agency remains unconvinced about the long-term stability of this technology. The Agency realizes that this technology has been in use only since the early 1980's and thus, there is little data available on long-term effectiveness. Recent studies conducted by Dr. Drexler, concluded that the addition of iron filings changes the leaching fluids characteristics by increasing the pH and lowering Eh and DO to levels that are unlike most natural environments wherre the wastes would be disposed (e.g., an environment where iron is constantly added to the landfill). The study found that the increase in pH (lowering of hydrogen ion activity) alone will lower the solubility of Pb in the test and insure a greater frequency of "passes." The Agency infers from this that the immediate test conditions would not be representative of the long-term landfill conditions. In the actual landfill, oxygen would defuse in to oxidize the metal filings increasing Eh and DO, decreasing pH. This would act to remove the initial adsorption of lead on the iron filings and results in leaching toxic levels of lead into the environment. This is evident from the TCLP tests done on waste sand from the Nacogdoches landfill that showed lead concentrations in the extracts ranging from 2.81 mg/l to 11.6 mg/l. Therefore, the addition of filings gives but a temporary effect unlike the long lasting effects obtained through microencapsulation or other true treatment technologies which substantially reduce metal mobility.

The Agency continues to believe that this treatment should be classified as impermissible dilution. The Agency has concluded that this form of stabilization is inadequate to minimize the threats posed by land disposal of metal-containing hazardous wastes. EPA, therefore considers this technology "impermissible dilution" in accordance with 40 CFR 268.3. Although the addition of iron dust filings is considered treatment under 260. 1 0, the Agency does not believe it is adequate treatment; but merely the addition of material as a substitute for adequate treatment and therefore constitutes impermissible dilution. See 40 CFR 268.3 (b), 54 FR at 48494 (November 1989), and 55 FR at 22532 (June 1, 1990).

The Agency is codifying this determination by amending 40 CFR 268.3 to read as follows:

40 CFR 268
§ 268.3 Dilution prohibited as a substitute for treatment
* * *

(d) It is a form of impermissible dilution, and therefore prohibited, to add iron filings or other metallic forms of iron to lead-containing hazardous wastes in order to achieve any land disposal restriction treatment standard for lead. Lead-containing wastes include D008 wastes (wastes exhibiting a characteristic due to the presence of lead), all characteristic wastes containing lead as an underlying hazardous constituent, listed wastes containing lead as a regulated constituent, and hazardous media containing any of the aforementioned lead-containing wastes.

* *

The Agency does not agree with the commenter's suggestion that an alternative analytical testing procedure be used since the waste is disposed of in a monofill. EPA has established the TCLP as the official required method for determining whether a waste is toxicity characteristic hazardous. EPA's determination of the use of the TCLP was finalized on March 29, 1990 (55 FR 11798). This issue is not being reopened in this rulemaking. However, should this comment be deemed to require a response, EPA reviewed the suitability for testing the leachability of lead in foundry sand and continues to believe that TCLP testing is appropriate for determining the characteristic of hazardousness for metal-bearing waste streams. This issue is further discussed in the Technical Memorandum entitled "Iron Dust Treatment of Lead-Bearing Foundry Sand," dated September 15, 1995, and can be found in the Administrative Record for this rulemaking.

Issue: FOUN1-069 Respondent: TTS

Dcn: PH3P069 Extension: CBI: N
Commenter: ENVIRONMENTAL TECHNOLOGY COUNCIL

Comment Number: 00021

//COMM21
//RESPTTS
//SUBJFOUN1-069

THE ETC SUPPORTS EPA"S PROPOSAL TO CLASSIFY AS IMPERMISSIBLE DILUTION THE USE OF IRON DUST OR FILINGS AS STABILIZING AGENTS FOR CERTAIN CHARACTERISTIC WASTES. ETC AGREES FULLY WITH EPA"S DISCUSSION IN THE PREAMBLE, 60 FR 11731, AND ADDS FURTHER THAT NO CHEMICAL REACTION OR POZZOLANIC REACTION IS POSSIBLE FROM IRON DUST OR FILINGS. THEREFORE MICROENCAPSULATION OR STABILIZATION IS NOT TAKING PLACE, ONLY DILUTION. THERE IS NO CHEMISTRY THAT CAN BE CONTRIVED TO JUSTIFY THAT METALS SUCH AS LEAD ARE BEING PERMANENTLY BOUND IN A NON-LEACHABLE MATRIX, WHEN USING IRON DUST OR FILINGS AS A STABILIZING AGENT.

//ENDC21

RESPONSE

[The Agency thanks the commenter for their support.]

Issue: FOUN1-086 Respondent: TTS

Dcn: PH3P086 Extension: CBI: N
Commenter: HERITAGE ENV SERVICES, INC

Comment Number: 00007

//COMM7
//RESPTTS
//SUBJFOUN1-086

REGULATING SPECIFIC PRACTICES BY RULE, RATHER THAN RIGOROUSLY ENFORCING EXISTING ADEQUATE STATUTORY AND REGULATORY PROVISIONS, WILL ADD REDUNDANT REGULATIONS THAT WILL ONLY SERVE TO COMPLICATE THE LDR PROGRAM. EPA HAS PROPOSED TO PROHIBIT THE SPECIFIC PRACTICE OF ADDING IRON AS A STABILIZATION REAGENT. EPA MADE A CONVINCING ARGUMENT (60 FR 11731) THAT THIS PRACTICE CONSTITUTES IMPERMISSIBLE DILUTION. IF THIS IS THE CASE, EPA, OR THE APPROPRIATE STATE REGULATORY AGENCY, SHOULD TAKE ENFORCEMENT ACTION AGAINST FACILITIES EMPLOYING THIS METHOD USING THE EXISTING DILUTION PROHIBITION AND THE TECHNICAL ARGUMENT PRESENTED IN THE PROPOSED RULE. CURRENT REGULATORY PROVISIONS AND THE TCLP TEST METHOD ARE SUFFICIENT TO DETERMINE COMPLIANCE WITH LDR.

//ENDC7

RESPONSE

The Agency thanks the commenter for their support on this issue. The Agency is codifying the determination that the addition of iron to a characteristically hazardous lead waste is impermissible dilution (i.e. confirming that the practice already is prohibited under existing dilution prohibition rules).

Issue: FOUN1-100 Respondent: TTS

Dcn: PH3P100 Extension: CBI: N
Commenter: BEVERIDGE & DIAMOND, P.C.

Comment Number: 00001

//COMM1
//RESPTTS
//SUBJFOUN1-100

OUR CLIENT IS PARTICULARLY CONCERNED ABOUT ONE ASPECT OF EPA"S PHASE III PROPOSED RULE, RELATING TO THE PROPOSED CODIFICATION OF THE PRINCIPLES SET FORTH IN ITS MAY 23, 1994 "RCRA POLICY STATEMENT: CLARIFICATION OF THE LAND DISPOSAL RESTRICTIONS" ["LDR"] DILUTION PROHIBITION AND COMBUSTION OF INORGANIC METAL-BEARING HAZARDOUS WASTES." IN THE COURSE OF ITS PREAMBLE DISCUSSION OF THE LDR DILUTION PROHIBITION AS IT RELATES TO THE COMBUSTION OF INORGANIC METAL-BEARING HAZARDOUS WASTES, EPA STATES THAT:

[T]HE AGENCY IS AWARE OF A PRACTICE WITHIN THE FOUNDRY INDUSTRY THAT RECYCLES FOUNDRY SAND BY THERMALLY OXIDIZING IMPURITIES. IT IS EPA"S VIEW THAT THIS PROCESS WOULD VIOLATE THE POLICY AGAINST COMBUSTION OF INORGANICS, UNLESS THE FOUNDRY SAND BEING OXIDIZED CONTAINS TOXIC ORGANIC CONSTITUENTS OR HAS A SIGNIFICANT ORGANIC COMPONENT.

60 FED. REG. AT 11,731.

EPA IN THE PREAMBLE DOES NOT ELABORATE ON THE BASIS FOR ITS IMPLICIT DETERMINATION -- REFLECTED IN THE FOREGOING STATEMENT -- THAT RECYCLED FOUNDRY SAND IS A SOLID AND HAZARDOUS WASTE SUBJECT TO RCRA SUBTITLE C REGULATION, INCLUDING THE REQUIREMENTS OF THE LDR PROGRAM. NEVERTHELESS, IT APPEARS THAT THE AGENCY"S INCLUSION OF THAT STATEMENT IN THE PROPOSED PHASE III RULE IS AN OUTGROWTH OF ITS ONGOING DISCUSSIONS WITH THE FOUNDRY INDUSTRY CONCERNING THE REGULATORY STATUS OF RECYCLED FOUNDRY SAND, REUSED IN CASTING AND MOLDING OPERATIONS. OUR CLIENT IS CONCERNED THAT, BY INTERJECTING ISSUES INTO THE PHASE III SAND, EPA IS SHORT-CIRCUITING THOSE ONGOING DISCUSSIONS IN A

MANNER THAT COULD UNDULY HINDER THE AGENCY"S AND INDUSTRY"S ISSUES THAT HAVE BEEN RAISED TO DATA BY EPA CONCERNING FOUNDRY JUDGEMENTS IN THE PHASE III RULE CONCERNING ISSUES RELATING TO THE THERMAL RECONDITIONING OF FOUNDRY SAND, INCLUDING WHETHER SUCH PROCESSING IMPLICATES THE "DILUTION PROHIBITION" AS IT RELATES TO THE "COMBUSTION" OF INORGANIC METAL-BEARING "WASTES", EPA SHOULD ADDRESS SUCH ISSUES COMPREHENSIVELY IN THE CONTEXT OF ITS ONGOING DISCUSSIONS WITH THE FOUNDRY INDUSTRY CONCERNING RCRA ISSUES PERTAINING TO RECYCLED FOUNDRY SAND.

//ENDC1

RESPONSE

The commenter requested clarification of its policy regarding the recycling of foundry sand by thermal oxidation. The commenter points out that there have been ongoing discussions with the Foundry industry with respect to the regulatory status of recycled foundry sand that is reused in casting and molding operations.

The Agency acknowledges that there have been ongoing discussions between foundry industry representatives and the Agency regarding the regulatory status of the practice of recycling foundry sand by thermal oxidization of the impurities. However, the Agency notes that this issue is outside the scope of this rulemaking. This rulemaking only addresses the issues related to the addition of iron filings to spent foundry waste as a method of treatment.

Issue: FOUN1-105 Respondent: TTS

Dcn: PH3P105 Extension: CBI: N
Commenter: NON-FERROUS FOUNDERS" SOCIETY

Comment Number: 00001

//COMM1
//RESPTTS
//SUBJFOUN1-105

THE FOUNDRY INDUSTRY AS A WHOLE IS ONE OF THE NATION"S LEADING RECYCLERS. THE BASIC FEEDSTOCK FOR MOST CASTINGS IS SCRAP METAL, WHICH IN THE ABSENCE OF A VIABLE METALCASTING INDUSTRY, WOULD OTHERWISE BE DESTINED FOR DISPOSAL IN LANDFILLS. IN ADDITION, THE OVERWHELMING MAJORITY OF FOUNDRIES EMPLOY A SEND MOLDING PROCESS WHEREIN MOLTEN METAL IS POURED INTO A SAND MOLD AND SOLIDIFIES INTO A DESIRED SHAPE. THE SAND USED IN THIS PROCESS IS TYPICALLY RECYCLED AND REUSED BY THE FOUNDRY UP TO AS MANY AS 100 TIMES. FEW OTHER INDUSTRIES CAN BOAST AS HIGH AS RECYCLING RATE IN THEIR MANUFACTURING PROCESSES.

METALCASTING OPERATIONS ARE SUBJECT TO A HOST OF ENVIRONMENTAL AND SAFETY AND HEALTH STANDARDS, REFLECTING TO SOME DEGREE THE EXTREME CONDITIONS AND COMPLEX MATERIALS INHERENT IN THE INDUSTRY"S CORE ACTIVITIES. THE FACT THAT SUCH STANDARDS ARE NEITHER UNIFORMLY IMPOSED NOR AS STRINGENTLY ENFORCED ON FOUNDRIES IN OTHER COUNTRIES AROUND THE WORLD PLACES U.S. FOUNDRIES AT A SEVERE COMPETITIVE DISADVANTAGE IN INTERNATIONAL TRADE. THAT THE INDUSTRY PERSISTS AT ALL IN SPITE OF THESE PRESSURES IS SIMPLY BECAUSE FOUNDRIES PROVIDE GOODS WHICH HAVE NO ECONOMIC SUBSTITUTES.

DESPITE THE BURDEN THEY IMPOSE, FOUNDRIES MAKE CONCERTED EFFORTS TO BE GOOD NEIGHBORS AND TO COMPLY WITH ALL ENVIRONMENTAL REGULATIONS. HOWEVER, THE INDUSTRY IS CONCERNED THAT PROPOSED NEW REGULATIONS BE BASED ON SOUND SCIENCE AND VALID COST/BENEFIT ANALYSES. REGRETTABLY, THIS DOES NOT APPEAR TO BE THIS CASE WITH REGARD TO THE AGENCY"S PROPOSED RULE "LAND DISPOSAL RESTRICTIONS - PHASE III: DECHARACTERIZED WASTEWATERS, CARBAMATE AND ORGANOBROMINE WASTES AND SPENT

POTLINERS" AS PUBLISHED IN THE MARCH 2, 1995 FEDERAL REGISTER (VOLUME 60, NUMBER 41), PAGES 11702-11766.

THE NON-FERROUS FOUNDERS" SOCIETY FULLY SUPPORTS THE POSITIONS AND ARGUMENTS PUT FORTH BY THE AMERICAN FOUNDRYMEN"S SOCIETY IN RESPONSE TO THIS PROPOSED RULE, AS WELL AS THE SCIENTIFIC AND TECHNICAL DISCUSSION OF THE CHEMICAL REACTIONS OF THE USE OF IRON FILINGS TO LEAD BEARING WASTE A SUBMITTED BY RMT, INC. WE ARE CONFIDENT THAT A THOROUGH REVIEW OF THE DOCKET WILL CLEARLY DEMONSTRATE THAT THE AGENCY"S PROPOSAL TO DISALLOW THIS PRACTICE AS IMPERMISSIBLE DILUTION UNDER 40 CFR 268.3 IS NEITHER SUPPORTED NOR JUSTIFIED. RATHER, RECORDS CLEARLY SHOW THAT THE ADDITION OF SMALL AMOUNTS OF IRON FILINGS IS AN EFFECTIVE TREATMENT FOR LEAD-BEARING WASTES, AND TCLP RESULTS REGULARLY AND ROUTINELY SUPPORT THIS FACT.

WE ALSO BELIEVE THAT THE AGENCY"S COMMENTS ON THE INDUSTRY"S PRACTICE OF RECYCLING FOUNDRY SAND BY THERMALLY OXIDIZING IMPURITIES ARE SIMILARLY UNFOUNDED. MOREOVER, IT IS SOMEWHAT IRONIC THAT THE DEVELOPMENT OF THIS TECHNOLOGY, WHICH EFFECTIVELY REDUCES WASTE BY MORE THAN 80% WHILE RETURNING RAW MATERIALS TO THE CASTING PROCESS, HAS BEEN BOTH LAUDED AND, IN FACT, PARTIALLY FUNDED BY OTHER GOVERNMENT AGENCIES IN RECENT YEARS. ONCE AGAIN, NFFS DRAWS SPECIFIC ATTENTION AND FULLY CONCURS WITH THE AFT COMMENT IN THIS REGARD.

THE NON-FERROUS FOUNDERS" SOCIETY REMAINS CONVINCED THAT THE AGENCY CAN SHOW NO EVIDENCE OF ENVIRONMENTAL HARM CAUSED BY THE THERMAL RECLAMATION OF FOUNDRY SAND, NOR CAN IT JUSTIFY THE DISALLOWANCE OF THE PROVEN TREATMENT METHOD OF ADDING IRON FILINGS TO FOUNDRY WASTE PRIOR TO THEIR DISPOSAL. WE ARE CONFIDENT THAT UPON PROPER CONSIDERATION OF THE FACTS IN THE DOCKET, THE AGENCY WILL COME TO REALIZE THAT NEITHER SOUND SCIENCE NOR VALID COST/BENEFIT ANALYSES HAVE BEEN APPLIED IN THIS REGARD, AND THAT THIS PROPOSED RULE IS BOTH UNNECESSARY AND UNJUSTIFIED.

//ENDC1

RESPONSE

The NFFS objected to EPA's position against addition of iron dust to foundry sand and requested clarification of its policy regarding the recycling of foundry sand by thermal oxidation. The main points raised by NFFS are:

1. supports the positions and arguments put forth by the American Foundrymen's Society (AFS)

response, which objected to EPA's position against addition of iron dust to foundry sand;

2. A valid cost/benefit analysis has not been applied in this proposed rule.

The Agency's determination that the addition of iron filing constitutes impermissible dilution is predicated on the fact that the adsorption of soluble lead on to the iron surface is a reversible reaction and once the iron surfaces oxidize, the ability of the additive to scavenge soluble metals is diminished. Therefore, the treatment is not permanent. In addition, adsorption alone is not a reliable method of permanently immobilizing lead. The longevity of treatment cannot be measured by the TCLP test, which provides only a snapshot of the leachable constituents under the test condition at the time of analysis.

Studies conducted by Dr. Drexler, concluded that the addition of iron filings changes the leaching fluids characteristics by increasing the pH and lowering Eh and DO to levels that are unlike most natural environments. The study found that the increase in pH (lowering of hydrogen ion activity) alone will lower the solubility of Pb in the test and insure a greater frequency of "passes." The Agency infers from this that the immediate test conditions would not be representative of the long-term landfill conditions. In the actual landfill, oxygen would defuse in to oxidize the metal filings increasing Eh and DO, decreasing pH. This would act to remove the initial adsorption of lead on the iron filings and results in leaching toxic levels of lead into the environment. This is evident from the TCLP tests done on waste sand from the Nacogdoches landfill that showed lead concentrations in the extracts ranging from 2.81 mg/l to 11.6 mg/l. Therefore, the addition of filings gives but a temporary effect unlike the long lasting effects obtained through microencapsulation or other true treatment technologies which substantially reduce metal mobility.

The Agency continues to believe that this treatment should be classified as impermissible dilution. The Agency has concluded that this form of stabilization is inadequate to minimize the threats posed by land disposal of metal-containing hazardous wastes. EPA, therefore considers this technology "impermissible dilution" in accordance with 40 CFR 268.3. Although the addition of iron dust filings is considered treatment under 260. 1 0, the Agency does not believe it is adequate treatment; but merely the addition of material as a substitute for adequate treatment and therefore constitutes impermissible dilution. See 40 CFR 268.3 (b), 54 FR at 48494 (November 1989), and 55 FR at 22532 (June 1, 1990).

The Agency is codifying this determination by amending 40 CFR 268.3 to read as follows:

40 CFR 268
§ 268.3 Dilution prohibited as a substitute for treatment

* * *

(d) It is a form of impermissible dilution, and therefore prohibited, to add iron filings or other metallic forms of iron to lead-containing hazardous wastes in order to achieve any land disposal restriction treatment standard for lead. Lead-containing wastes include D008 wastes (wastes exhibiting a characteristic due to the presence of lead), all characteristic wastes containing lead as an underlying hazardous constituent, listed wastes containing lead as a regulated constituent, and hazardous media containing any of the aforementioned lead-containing wastes.

* *

Regarding the comment on foundry industry's practice of reclaiming foundry sand by thermal oxidization of impurities, the Agency notes that this issue is outside the scope of this rulemaking. This rulemaking only addresses the issues related to the addition of iron filings to spent foundry waste as a method of treatment.

With respect to the comment on cost/benefit analysis, the Agency disagrees that a valid cost/benefit analysis was not performed. The reader is refered to the Regulatory Impact Analysis (RIA) published as part of the proposed rule, which also includes a cost/benefit analysis.

Issue: FOUN1-108 Respondent: TTS

Dcn: PH3P108 Extension: CBI: N
Commenter: GMD ENV SYSTEMS, INC

Comment Number: 00001

//COMM1
//RESPPGS
//SUBJFOUN1-108

IN THAT MARCH 2, 1995 PROPOSED, ON PAGE 11731, THE AGENCY MAKES THE FOLLOWING STATEMENT.

"THE AGENCY IS AWARE OF A PRACTICE WITHIN THE FOUNDRY INDUSTRY THAT RECYCLES FOUNDRY SAND BY THERMALLY OXIDIZING IMPURITIES. IT IS EPA"S VIEW THAT THIS PROCESS WOULD VIOLATE THE POLICY AGAINST COMBUSTION OF INORGANICS, UNLESS THE FOUNDRY SAND BEING OXIDIZED CONTAINS TOXIC ORGANIC CONSTITUENTS OR HAS A SIGNIFICANT ORGANIC COMPONENT (AS DESCRIBED ABOVE).

THE FIRST SENTENCE IS A CORRECT STATEMENT. THERE ARE FOUNDRIES WITHIN THE FOUNDRY INDUSTRY WHO RECYCLE (REUSE) FOUNDRY SAND BY CALCINING A PORTION OF THE RETURN SAND. HOWEVER, THE REMAINDER OF THAT STATEMENT IS NOT CORRECT. RECYCLING RETURN SAND IN A FOUNDRY PROCESS IS NOT A "TREATMENT" OF WASTE, THEREFORE, A FOUNDRY UTILIZING THIS RECYCLING EQUIPMENT IS NOT IN VIOLATION OF THE POLICY AGAINST COMBUSTION OF INORGANIC.

THE PROCESS OF CALCINING A RETURN SAND WITHIN THE FOUNDRY PROCESS IS NOT TREATMENT OF A WASTE, I.E. RETURN SAND IS NOT A WASTE.

THE PROCESS REFERRED TO IS A PART OF THE FOUNDRY PROCESS. IT MERELY DIRECTS A CERTAIN PORTION OF THE RETURN SAND TO THE RECYCLING EQUIPMENT WHICH CALCINES THE FEED MATERIAL. AFTER THE SAND IS PROCESSED THROUGH THE CALCINER, IT IS RETURNED TO THE FOUNDRY PROCESS FOR REUSE IN IT"S ORIGINAL STATE.

FURTHERMORE, THE RECYCLING PROCESS DOES NOT OXIDIZE THE INORGANIC, IN THIS CASE SILICA, I.E. SILICON DIOXIDE (SIO2).

WE WISH TO DIRECT YOUR ATTENTION TO THE AGENCY"S DEFINITION OF THERMAL TREATMENT

"THERMAL TREATMENT IS ANY METHOD, TECHNIQUE, OR PROCESS, INCLUDING NEUTRALIZATION, DESIGNED TO CHANGE THE PHYSICAL, CHEMICAL, OR BIOLOGICAL CHARACTER OF COMPOSITION OF THE WASTE".

ALSO PLEASE NOTE THE DEFINITION OF CALCINING,

"TO HEAT TO A TEMPERATURE BUT WITHOUT FUSING IN ORDER TO DRIVE OFF VOLATILE MATTER".

IT SHOULD BE NOTED THAT THE CALCINING PROCESS DOES NOT CHANGE THE CHEMICAL , PHYSICAL OR BIOLOGICAL CHARACTER OR COMPOSITION OF THE SAND, I.E. SILICA, I.E. SILICON DIOXIDE (SIO2).

BASED ON THAT DEFINITION, THE FOUNDRY PROCESS OF USING EQUIPMENT DESIGNED FOR THE EXPRESS PURPOSE OF RECOVERING AND REUSING A MATERIAL PRODUCT, IN THIS CASE A NATURAL RESOURCE, DOES NOT CONSTITUTE TREATMENT.

//ENDC1

RESPONSE

The commenter requested clarification of EPA's policy regarding the recycling of foundry sand by thermal oxidation. The commenter asserts that thermal treatment of foundry sand is a calcining operation and not incineration. The calcination process takes place at a lower temperature than glassification. There is no melting of the solid materials but a volatilization of some waste components. The Agency notes that this issue is outside the scope of this rulemaking. This rulemaking only addresses the issues related to the addition of iron filings to spent foundry waste as a method of treatment.

Issue: FOUN1-123 Respondent: TTS

Dcn: PH3P123 Extension: CBI: N
Commenter: CHESAPEAK SPECIALTY PRODUCTS

Comment Number: 00001

//COMM1
//RESPTTS
//SUBJFOUN1-123

SSPC RECOMMENDATIONS
SSPC SUGGESTS THE FOLLOWING LANGUAGE FOR A RULE:

ALL WASTE GENERATED DURING BLAST CLEANING OF LEAD PAINTED STEEL STRUCTURES SHALL BE DISPOSED OF A HAZARDOUS WASTE REGARDLESS OF THE TYPE; STEEL, MINERAL, SLAG, ETC. ABRASIVE USED FOR BLAST CLEANING. WASTE IS DEFINED AS SPENT ABRASIVE, PAINT CHIPS, RUST, MILL SCALE, DUST, AND OTHER DEBRIS NOT INTENDED FOR RECYCLING.

//ENDC1

RESPONSE

The Agency recognizes that the waste residues resulting from blast cleaning could contain a mixture of lead paint and metallic iron fines and therefore, could exhibit toxicity characteristic for lead. However, the Agency notes that the use of iron abrasives for removing lead paint from steel is part of the blast cleaning process and therefore, the presence of iron fines in the residues would not result in impermissible dilution. The current rulemaking only addresses dilution prohibition as it applies to processes that treat hazardous wastes and not for processes that generate a waste. The Agency also notes that it is beyond the scope of this rulemaking to list all lead abatement waste as hazardous.

LEACHING CHARICTARISTICS AND ASSESSMENT OF ABRASIVE BLASTING WASTE FROM SHIP MAINTENANCE FACILITIES AND SANDBALSTING CONTRACTOR SITES

By

Jenna Jambeck Carlson

A THESIS PRESENTED TO THE GRADUATE SCHOOL
OF THE UNIVERSITY OF FLORIDA IN PARTIAL FULFILLMENT
OF THE REQUIREMENTS FOR THE DEGREE OF
MASTER OF ENGINEERING

UNIVERSITY OF FLORIDA

1998

This thesis is dedicated to my husband, Brian John Carlson.

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First, I would like to thank Dr. Timothy Townsend, my committee chairman, for giving me the opportunity to get my graduate degree and for all his support and encouragement throughout my graduate career. I would also like to thank Dr. Lamar Miller for his advice and discussion of both solid waste and real life issues. I am also grateful to Dr. J.J. Delfino for his water chemistry expertise, discussion, and review of this thesis.

I would like to express sincere appreciation to all of the graduate students who assisted me on this project with sampling and analyzing. These students include Allan Brantley, William Craven, Brian Messick, and William Weber. Thanks also to Yong-Cul Jang for his support and advice throughout the lysimeter study. Special thanks to Thabet Tolaymat for helping me on the longest sampling trip, his periodic assistance in draining my lysimeters, and for his work with the AA-spectrophotometer.

I would like to thank the Florida Center for Solid and Hazardous Waste for funding this research. I would like to also thank all of the industry professionals who helped me to know more about abrasive blasting media than I ever thought I would. I appreciate the contractors who allowed me to sample at their sites throughout the state of Florida, their acceptance and help was crucial to this study.

I am so grateful for the wonderful family I have and I would like to thank my mom, dad, and step mom for their encouragement, love, and support. I have sincere appreciation to my brother, Jay Jambeck, for his editing, advice, and belief in me. Lastly, I would like to thank my husband, Brian Carlson, for his never-ending love, support, encouragement, patience, and many hours of help in the lab and at home. This thesis would not be what it is today without him and I don't think words can express the love and gratitude I feel towards him.

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CHAPTER 1
INTRODUCTION

Abrasive Blasting

Abrasive blasting removes paint and coatings from surfaces. It proves advantageous over chemical stripping in many cases because while removing coatings, the abrasive blasting also prepares the surface for repainting. Abrasive blasting is also utilized to prepare clean new surfaces (e.g. steel) for a first coat of paint. The process of abrasive blasting involves a high-pressure spray of media at the surface. After contacting the surface, the media falls to the ground carrying materials from the blasted surface with it. This used media is a solid waste, but many times has not been recognized as such in the past. gr. C

The waste abrasive blasting media (ABM) has many soil-like properties and many generators have allowed this waste to accumulate on site. Concerns for waste contamination have focused primarily on the heavy metals in this waste stream. Many heavy metals are used in coatings for pigments, anti-corrosive agents, and biocides (Lambourne, 1987). This thesis discusses the management of this waste stream and begins to characterize the metals in waste ABM from a few specific generators to assess the possible risk to human health and the environment. Management concerns with this waste include direct human exposure, as well as leaching characteristics of the waste.

Management

Because the proper management of ABM waste stream is a relatively new concern, the correct management techniques and regulatory practices required for generators have not always been clearly outlined. Previous research by the author involved the development of a management strategy for generators to follow. This strategy provided a stepwise approach to evaluate options for management as well as the analytical testing needed for each option (Figure 1-1). With a non-hazardous waste a generator may simply dispose of it in an acceptable lined landfill, recycle it, or continue testing for other less expensive potential disposal options including disposal in an unlined landfill or land application (Carlson and Townsend, 1998).

Regulations and Standards

Regulations exist regarding the leachability of chemicals from a waste. As seen in the flow chart, a solid waste is determined to be hazardous or not through the Toxicity Characteristic Leaching Procedure (TCLP) (waste ABM is not listed and typically possesses no other hazardous characteristics). Once a waste has been determined to be non-hazardous, other analytical assessments may be made to assist in management decisions. A waste can potentially cause a threat to human health and the environment through direct human exposure and groundwater contamination.

Risk-based standards or goals are used to assess the direct exposure threat of this solid waste. Risk-based standards are in use or will be in use soon by many federal and state regulatory groups. These standards are developed through a "risk assessment" of contaminants including a hazard identification, dose-response assessment, exposure estimate, and risk-characterization (Andrews, 1997). Many assumptions are made in these analyses, making them controversial and open to challenge. Regardless of the validity of these standards at this time, they do exist at federal, state, and local levels, and so they must be considered.

or goals

Examples of risk-based standards include the soil screening guidelines (SSLs) written by the U.S. EPA in 1995, the sewage sludge application rules in Chapter 40 Part 503 of the Code of Federal Regulations, and the Florida Soil Cleanup Goals (1996). These standards are used as tools for determining "cleanliness" in site assessment.

Other leaching tests may be performed to assess the risk to groundwater from waste leachability, like the Synthetic Precipitation Leaching Procedure (SPLP). The concentration of chemicals in the SPLP leachate may be compared to Primary and Secondary drinking water standards. These standards have been adopted by many states as the maximum permissible level in groundwater supplies. Management of a solid waste such as ABM in a manner that results in off-site groundwater contamination above drinking water limits is typically not permitted.

The increased regulation of solid wastes ABM has confused many generators and added to their operating expenses. This research was a part of a project to develop best management practices for the abrasive blasting industry. A consistent regulation and management of this waste stream was needed. This research strives to highlight possible environmental concerns for this waste, and to characterize some waste through total metals and leachability. A proper management plan for this waste stream could conserve on analytical costs for the generator, while protecting the environment from potential contamination.

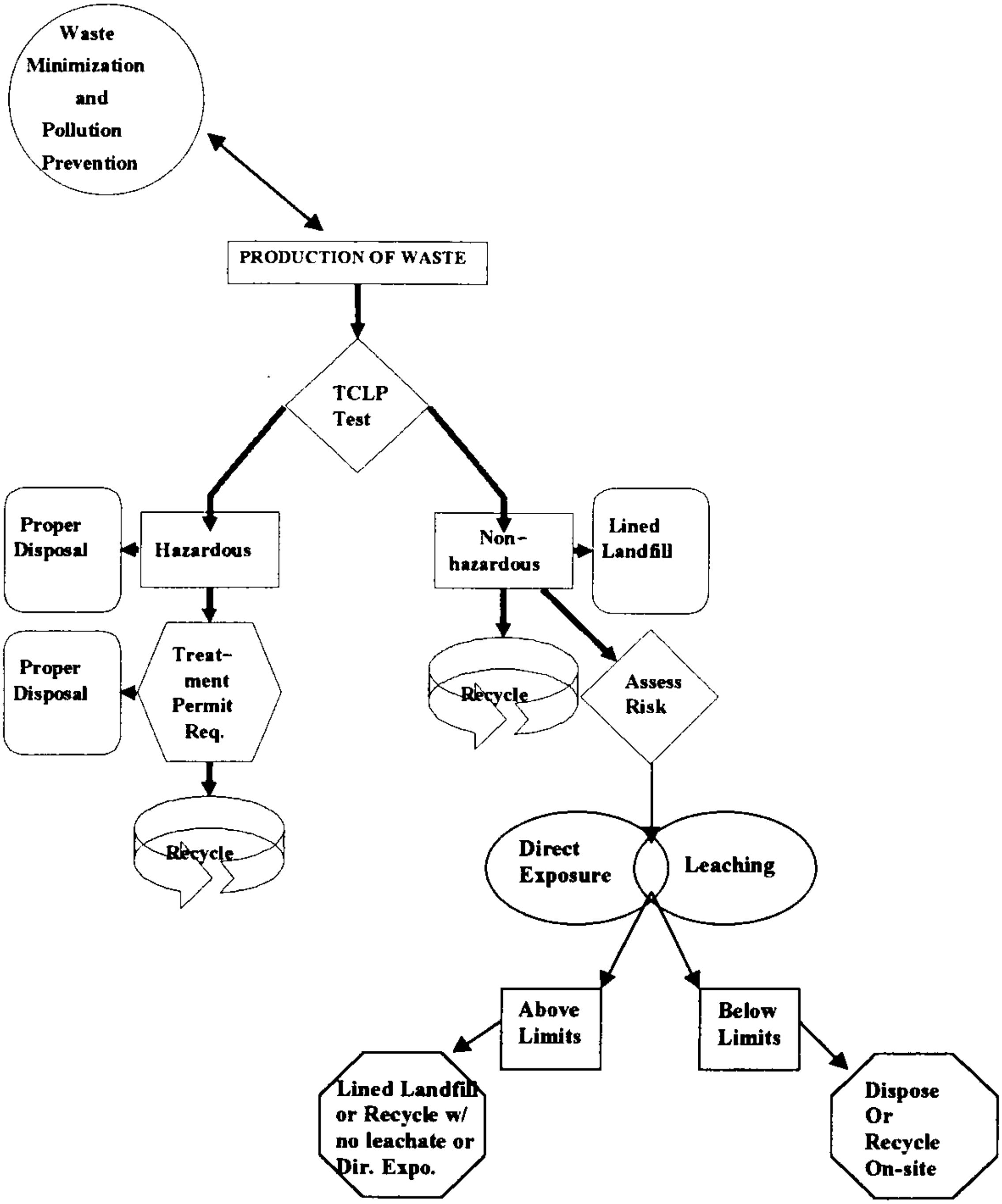


Figure 1-1. Management Flow Chart for ABM waste

Organization of Thesis

This thesis is divided into three separate papers. Each paper will eventually stand alone for publication. Chapter two and chapter three have similar formats for characterizing waste but discuss different waste streams in the ABM industry. These two waste streams generated by ship maintenance facilities and sandblasting contractors need to be separated because of the very different media and applications used by each generator. The leachability concerns of chapters two and three lead to the development of chapter four. Chapter four compares the batch leaching tests similar to those used in chapters two and three with a leaching column (lysimeter) study for the same waste streams. The goal of the lysimeter study was to provide more field-like conditions and then compare the results with the batch leaching procedures. All three chapters relate to each other and tie in the relationship of the management and characterization of this waste stream. Chapter five discusses conclusions to this research and includes ideas for possible future work.

CHAPTER 2
CHARACTERISTICS OF WASTE ABRASIVE BLASTING MEDIA FROM SHIP MAINTENANCE FACILITIES

Introduction

Ship maintenance facilities utilize abrasive blasting to remove coatings from ships and barges and to prepare those surfaces for painting. The process of abrasive blasting, which involves a high-pressure spray of an abrasive media at a surface, generates a solid waste. This waste is composed of the media itself as well as any material removed from the surface of the ship. The waste typically has sand and soil-like physical properties but these characteristics are also dependent on the type of media used.

Normally, the abrasive blasting is performed at a "dry dock" facility where the waste is allowed to accumulate around the ship on the dock surface. The waste must be removed periodically and then the waste is typically stored on site. It is not economical to remove small amounts of this waste and it is normally stockpiled until a large enough quantity accumulates to make transportation for disposal or recycling economically feasible. In some areas the waste may not be removed and allowed to accumulated on site or even fall into the water surrounding the dock area.

As with any solid waste, abrasive blasting media (ABM) waste must be properly stored and managed to minimize impact on human health and the environment. A main concern with waste ABM is the heavy metal content resulting from the paint and coatings or from the media itself. A waste pile could pose a risk to human health through direct exposure or through leachate produced when it rains. This chapter reports the results of research conducted to collect information necessary for the decision making process involved with the storage and management of waste ABM from ship maintenance facilities. This research characterized waste ABM from three ship facilities to address direct human exposure, leaching risks and assess the potential impacts this waste stream could have on the environment. While these results do not universally characterize waste ABM from ship maintenance facilities, the information provided does set a foundation for the potential concerns facility operators and regulators should address.

Background

Abrasive Blasting Media

Many different types of media are used for abrasive blasting. Silica sand has traditionally been the most widely utilized, but other media include coal slag, garnet, plastic, glass bead, steel shot/grit, and crushed walnut shells. Specific types of ABM are used for different processes depending on the media characteristics. These characteristics also dictate the options for reuse and recyclablility of the spent media (Townsend and Carlson, 1997). A recent study (1997) by the National Shipbuilding Research Program found that coal slag and copper slag comprise almost 90% of the ship rehabilitation and maintenance industry's use of abrasives. The other 10% is made up of steel grit and shot and sand media.

The most common abrasive blasting media encountered at ship maintenance facilities in this study was a coal slag media sold by the trade name, Black Beauty™. Coal slag is produced during the coal burning process when the bottom ash/slag (molten material) produced from the hot temperatures of coal combustion is rapidly quenched, shattering apart to create small irregular shaped particles. These particles are then graded and sold as ABM.

The major constituents of coal ash, aluminum and silicon, almost always occur in a virtually insoluble form of aluminosilicate (Wu and Chen, 1987). In general, the largest quantity of soluble material in coal ash is composed of calcium, magnesium, potassium, sodium sulfates, and anhydrous oxides. The soluble matter also includes several mg/L of iron, nickel, and zinc sulfates, as well as trace amounts of chromium, copper, lead, arsenic, and cadmium (Hart and DeLaney, 1978). The amount of trace metal contaminants in this slag media is variable and dependant on type and grade of coal burned as well as the plant operating procedures and conditions (Wu and Chen, 1987). The metal content of the unused slag media may also play a role in determining management requirements.

Origination of Metals in Waste ABM

Even though raw ABM may contain heavy metals, the traditional concern with ABM waste has been from metal contaminants introduced by the paint removal process. Coatings and paint contain various constituents, including binders, solvents, additives, primary pigments, and extenders. Many of these constituents may be either organic or inorganic. Typically the organic components are the binders and solvents, but additives, pigments and extenders may also be synthetic organic compounds. The inorganic components, usually composed of a metallic compound, are commonly primary pigments, additives, and extenders (Lambourne, 1987).

The principal pigment in use is titanium dioxide, which is a white pigment made popular because of fashion concerns. In the past, a common pigment used was lead silicate or sulfate, because other metals were used as additives and not pigments

(Lambourne, 1987). The toxicity of this metal has required the phasing out of the use of lead for many applications (Stoffer, 1997). However, lead contaminated ABM waste may still be encountered if an older coating is removed from a ship surface. Other highly toxic pigments including cadmium and chromium are normally used in specific industrial applications where needed and are being phased out of more general use (Lambourne, 1987).

Pigments are not the only metallic component of paints and coatings. Coatings and paints for ships also include additives such as anti-corrosive agents and biocides. Anti-corrosive agents help extend the life of the paint in the harsh marine environment and biocides minimize the growth of algae and barnacles (Munger, 1984). Controversial biocides include mercury and the butyltin compounds, including tributyltin. Because of its acute toxicity, mercury has been phased out and is often prohibited as use of a biocide (Munger, 1984). The butyltin compounds remain in use but have been found to bioaccumulate in the blubber of some marine animals (Kannan et al., 1997). To control the leaching of this compound in the aquatic environment, the Organotin Antifouling Paint Control Act of 1988 limits the use of tributyltin to ships over 25ft in length (except for aluminum hulls) and limits the overall leaching rate of a coating. However, there are currently no direct exposure, primary or secondary drinking water standards for this compound.

~~[illegible]~~

Table 2-1 is a list of common metals used for pigments, anti-corrosive agents, and biocides. The heavy metals evaluated in this research focused on the metals listed in the table, as well as other trace metals sometimes encountered in the unused coal slag media.

research has indicated that organic compounds are not usually encountered when dealing with waste ABM (Townsend and Carlson, 1997).

Direct human exposure limits

A non-hazardous waste is still a solid waste and is subject to state and federal regulation. When waste is allowed to accumulate on-site, as ABM typically is, it may be subject to direct exposure and groundwater contamination limits. Once a waste has been found to be non-hazardous, other analytical assessments may be made. The total metal concentration is a measure of the total amount of metal in a solid sample of the waste ABM. This metal content can be compared to both federal regulations and state direct exposure guidelines as presented in Table 2-2. Direct exposure limits are a tool to assess the contamination or cleanliness of a site. The U.S. Environmental Protection Agency has published a Soil Screening Guidance Document with limits (SSLs) for many contaminants in soil based on a risk-associated calculation. When the SSLs are exceeded further investigation may be required, but the result does not necessitate cleanup (U.S. EPA, 1995). Many states have their own soil screening, guidance levels, or goals. State limits may be more stringent than the federal limits, requiring further investigation at the state level.

Leaching model limits

Along with the risk-based concentration limit in the SSLs is a leaching concentration limit for total metals. This second set of total metal concentrations was calculated from the drinking water standards with a theoretical leaching model. First, the drinking water standard was multiplied by a dilution/attenuation factor of 20. This factor was selected by a "weight of evidence" approach by EPA. This overall factor accounted

Table 2-1. Application of Metals in Ship Coatings.

Metal	Pigment Color	Anti-corrosive	Biocide
Cadmium	Orange, Yellow, Red	Good (Red Compounds)	N/A
Chromium	Orange, Yellow, Green	Good (Green Compounds)	N/A
Copper	Red	Good	Yes
Iron	Blue, Yellow, Red, Black, Brown	Good	N/A
Lead	White, Red, Blue	Good	N/A
Nickel	Yellow	Good	N/A
Zinc	White, Yellow	Excellent	N/A

Regulation

A number of regulatory issues must be addressed in regard to the management of any solid waste, including waste ABM. The regulatory steps that must typically be evaluated for management have been previously summarized (Carlson and Townsend, 1998). Federal regulations require a generator to characterize waste produced as hazardous or non-hazardous. A hazardous waste must be managed strictly according to federal regulations. Waste ABM is not a listed hazardous waste and the characteristic most encountered to classify the waste as hazardous is toxicity.

Hazardous characteristic

The toxicity characteristic leaching procedure (TCLP) test is the assay prescribed by the EPA to determine whether a solid waste is hazardous by toxicity characteristics (40 CFR 261). In this test, a solid waste is extracted using an acetic acid based leaching solution, with a pH that is dependent on the buffering capacity of the waste. The leaching solution is designed to simulate anaerobic conditions within a landfill. TCLP leachate concentration limits have been established for a number of metals and organic compounds. If the leachate concentration from a waste is at or above these limits, it is hazardous. Past for dilution and attenuation in the environment for a 0.5-acre area. A total metal concentration was calculated that would result in the augmented drinking water standard. The model for this calculation incorporated the partition coefficient of each compound. Figure 2-1 is the equation used by the U.S. EPA to calculate the total metal concentration from the drinking water standards.

$$C_t = C_w\left(K_d + \frac{\theta_w + \theta_a H'}{\rho_b}\right)$$

Where C_t=screening level in soil (mg/kg)
C_w=target soil leachate concentration (mg/L)
K_d=soil-water partition coefficient (L/kg)
θ_w=water-filled soil porosity (assumed 0.3)
θ_a=air-filled soil porosity (assumed 0.13)
ρ_b=dry soil bulk density (assumed 1.5 kg/L)
H'=dimensionless Henry's Law Constant (H-atm-m^3/mol x 41(C.F.))

Figure 2-1. U.S. EPA Soil Screening Guidance Theoretical Leaching Equation

The EPA recognized that partition coefficients, especially for metals, are affected by many situational circumstances. The K_d may be affected by pH, oxidation-reduction potential, iron oxide content, soil organic matter content, cation exchange capacity, and major ion chemistry, among others (U.S. EPA, 1995). Therefore, some actual testing of a contaminated site should follow the theoretical values calculated.

Batch leaching limits

Drinking water limits, often used as groundwater limits, are state and federal regulatory limits that must not be exceeded. Federal groundwater limits may be supplemented by more stringent and extensive state regulations. Although the TCLP test is primarily used to determine hazardous characteristics, it is sometimes used to determine the potential impact of a waste on groundwater when the waste is stored or disposed in non-landfill conditions. A more suitable test for this scenario is the synthetic precipitation leaching procedure (SPLP). The SPLP assay uses a leaching solution made from nitric and sulfuric acid that simulates acid rain with a pH of 4.20 (sites located east of the Mississippi River). It is the preferred choice by many regulators for determining impacts of waste on groundwater(WDNR, 1997). Other than the leaching solution, which is less aggressive than the TCLP solution to simulate rainfall, all other aspects of the test remain the same as the TCLP test.

Table 2-2 contains primary and secondary federal drinking water standards, as well as the federal generic SSLs (risk-based and leaching) for a number of metals. The Florida soil cleanup goals are included as an example of state ~~regulatory standards~~ risk-based contaminant guidelines, for both a residential and an industrial setting.

Table 2-2. Regulations and Guidelines for metal concentrations.

Metal	Drinking water Primary (ug/L)	Drinking water Secondary (ug/L)	SSLs (mg/kg) Risk	SSLs (mg/kg) Leach.	Residential FSCG (mg/kg)	Industrial FSCG (mg/kg)
As	50	-	0.4	29	0.8	~~3.1~~ 3.7
Ba	2,000	-	5,500	1,600	~~5,200~~ 105	~~84,000~~ 87000
Cd	5	-	78	8	~~37~~ 75	~~600~~ 1300
Cr	100	-	390	38	290	430
Cu	-	1,000	N/A	N/A	~~N/A~~ 105	~~N/A~~ 12000
Fe	-	300	N/A	N/A	~~N/A~~ 23,000	~~N/A~~ 490,000
Pb	15	-	400	N/A	500	~~1,000~~ 920
Hg	2	-	23	23	~~23~~ 3.7	~~480~~ 28
Ni	100	-	1,600	130	~~1,500~~ 105	~~26,000~~ 28000
Se	50	-	390	5	390	~~9,900~~ 10,000
Ag	-	100	390	34	390	~~9,000~~ 9100
Zn	-	5,000	23,000	12,000	23,000	560,000

= TCLP [illegible]

Methodology

Sample Collection

The samples collected as part of this study all came from ship maintenance facilities located at a port in Tampa, Florida. Several different facilities were sampled on the same day (January 9,1998). Since metals were the primary pollutants of interest, nitric acid rinsed plastic containers and stainless steel sample utensils were used.

All samples were collected in 13-Liter containers. The containers were used to gather a large sample volume from each sample area to assure a representative sample of that area of the pile. The top of each sample area was scraped off and the sample taken from approximately 0.5-1m into pile. Samples were gathered systematically from a random starting point around the circumference of the piles, and encompassed a few weeks of compiled media. All sample areas were recorded and mapped for future reference. Table 2-3 contains descriptions and number of samples collected from each site.

Table 2-3. Ship Maintenance Facilities Sampled

Site	Media	Pile(s) Mass (kg)	Dimensions (m)	No. of samples
Ship Blast A	Coal slag	27,000	12x5x3	12
Ship Blast B	Coal Slag	54,000	18x9x2	6
Ship Blast C	Coal Slag	36,000/18,000	15x4x5/10x5x4	8

3 sites [illegible]

26

Unused ABM collected

Samples of raw ABM were obtained from the supplier to each ship maintenance facility. The samples were taken from 23-kg bags purchased from Standard Sand and Silica. As discussed earlier, metals may exist in the raw ABM, which could classify the material as hazardous (very rare) or in which leachate from the raw ABM could cause groundwater contamination problems. The raw samples were treated the same as the used samples and all of the same analyses were performed on these samples.

Sub-sampling

The 13-Liter containers collected at each site were mixed thoroughly in the lab. A sub-sample of 400g was taken from each bucket. Sub-sampling created a smaller volume for analytical analysis and ensured similar sample was used for both total metal and leaching analyses. A composite sample from each site was formed at a later time. The composite sample was used to determine if the waste was hazardous or not.

Analysis of Waste ABM

The waste ABM was tested for both total metal concentrations and leachable metal concentrations. Two primary leaching methodologies from EPA SW-846 were used, the TCLP (EPA Method 1311) and the SPLP (EPA Method 1312) For both leaching tests, 2 liters of appropriate fluid was added to 100g of the solid material. The solid and liquid was mixed for 18 hours in a rotary extractor, the leachate was filtered, and then preserved and stored according to the parameter of interest (preserved at a pH of <2 for metals). The metals chosen for examination from a leaching and groundwater contamination perspective consisted of metals that were detected in the total metal content of the samples.

The methods used for the digestion and analysis of the samples are also from the EPA SW-846 manual. These methods included 3050b for digestion of solid samples and methods 3010 and 3020 for digestion of liquid samples for the flame and furnace, respectively. Samples were analyzed on a Perkin Elmer 5100 atomic absorption spectrophotometer equipped with a flame and a furnace.

Results

TCLP Leaching

The composite samples from each ship maintenance facility were analyzed using the TCLP test to determine whether or not they were hazardous by toxicity characteristic. Table 2-4 contains the TCLP limits and results from this study.

Table 2-4. TCLP Limits and Results.

	As	**Ba**	**Cd**	**Cr**	**Pb**	**Hg**	**Se**	**Ag**
TCLP Limit	**5.0**	**100.0**	**1.0**	**5.0**	**5.0**	**0.2**	**1.0**	**5.0**
Det. Limit	.001	10	.001	.100	.010	.001	.010	1
Ship Site A	BDL	BDL	.004	BDL	.103	BDL	BDL	BDL
Ship Site B	BDL	BDL	.004	BDL	.171	BDL	BDL	BDL
Ship Site C	BDL	BDL	.005	BDL	.155	BDL	BDL	BDL

*Units mg/L, BDL=Below Detection Limit

Total Metals

Table 2-5 presents an overview of the total metal data for each metal including the detection limits, the percent of samples above the detection limit, and the maximum and minimum concentration for each metal. All metals analyzed for were 100% detected, except for cadmium and selenium, which were below the detection limit for all samples. The standard deviations for the arithmetic means of the data sets were high and variable so a log transformation was performed on each data set. The transformation was done to make the variances uniform to facilitate future comparisons (Berthouex and Brown, 1994). Figures 2-2 through 2-5 show the histograms for the distributions of zinc, lead, copper, and nickel, which fit the lognormal distribution.

Table 2-5. Total Metal Content in Ship Maintenance Waste ABM (mg/kg).

	As	**Cd**	**Cr**	**Cu**	**Fe**	**Pb**	**Ni**	**Se**	**Zn**
No. of Samples	23	23	23	23	23	23	23	23	23
Detection Limit	0.05	2.5	5	25	5	25	5	0.5	5
% Detects	100%	0%	100%	100%	100%	100%	100%	0%	100%
Minimum	0.23	N/A	39.7	62.19	42,881	25.6	41.7	N/A	119.7
Maximum	4.46	N/A	135.3	4,131	109,479	446	100.8	N/A	8,885
Geo. Mean	1.07	N/A	76.6	607.6	53,084	77.3	58.2	N/A	1,262
Geo. Std. Dev.	0.68	N/A	1.50	2.88	1.28	2.06	1.21	N/A	3.04
Arith. Mean	1.72	N/A	82.6	1,007	54,909	102	59.3	N/A	2,054
Arith. Stnd. Dev.	1.29	N/A	31.0	1,100	17,008	94.0	12.3	N/A	2006
Residential	0.8	75	210	[illegible]	[illegible]	400	[illegible]	[illegible]	[illegible]
Industrial	3.7	1300	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Leaching	29	8	38	–	–	–	130	[illegible]	[illegible]

SCTL values

[illegible] 95% limit

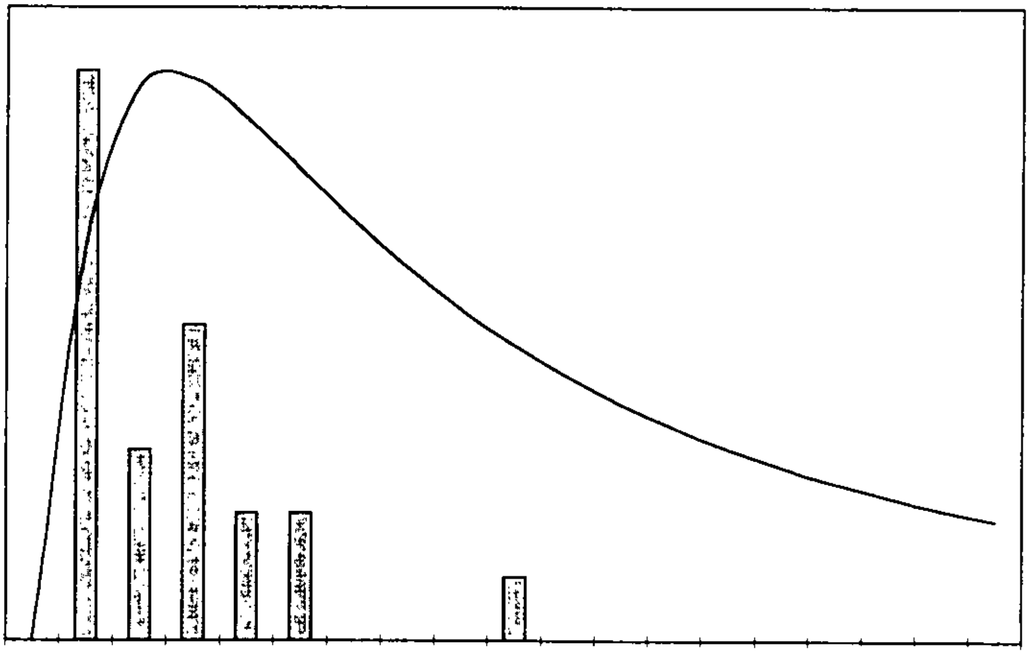


Figure 2-2. Zinc Histogram and Lognormal Distribution

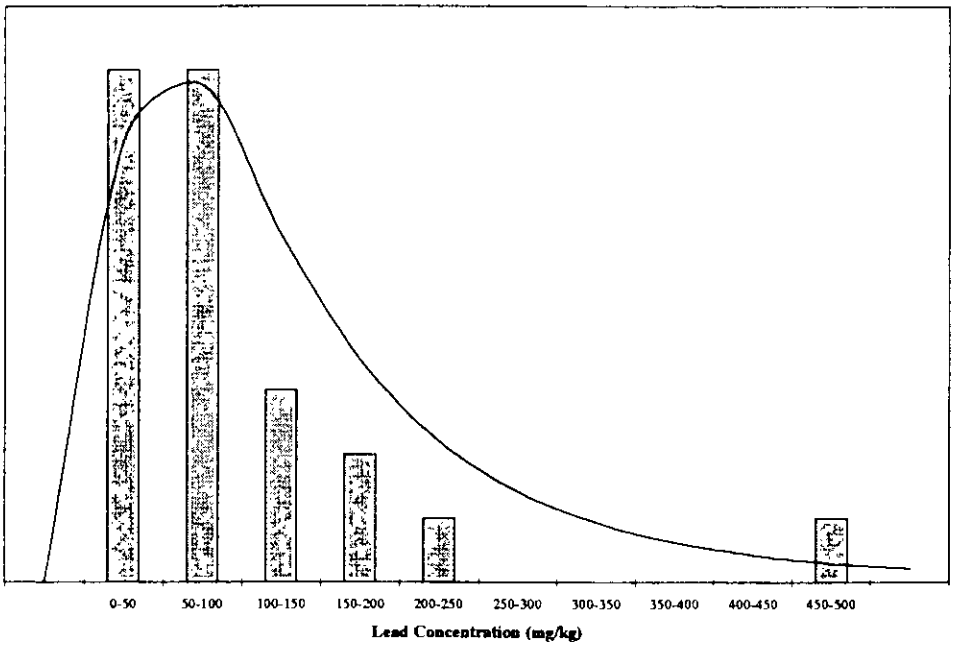


Figure 2-3. Lead Histogram and Lognormal Distribution.

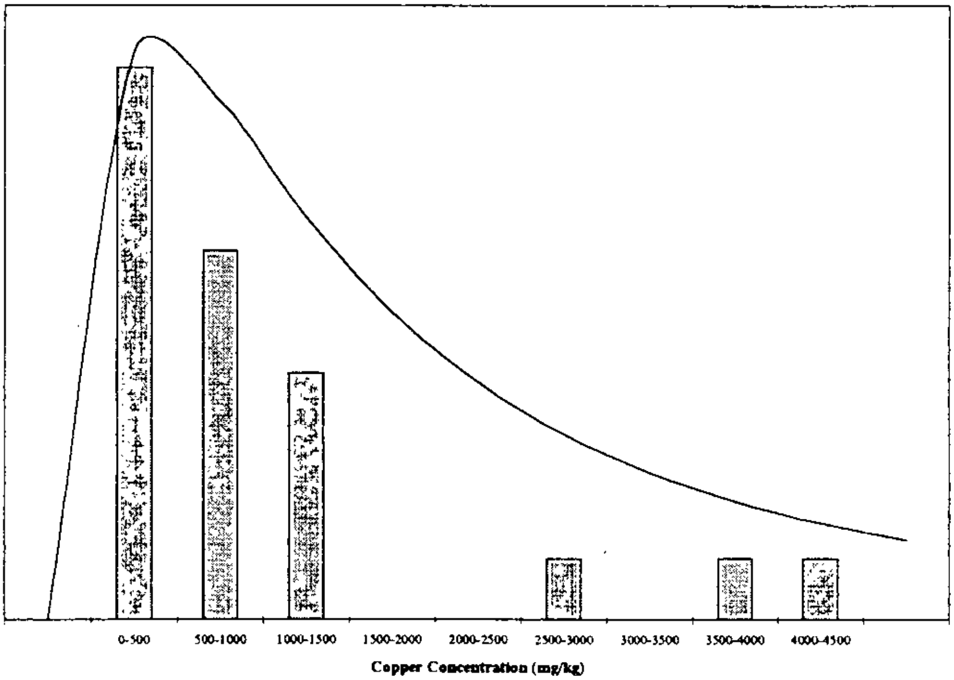


Figure 2-4. Copper Histogram and Lognormal Distribution.

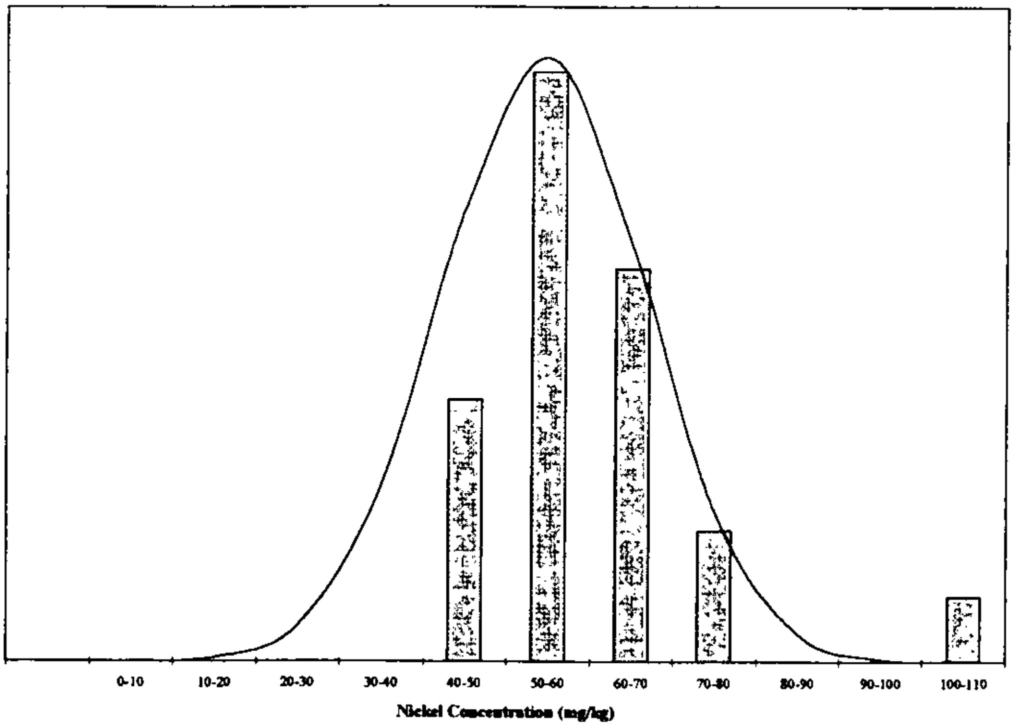


Figure 2-5. Nickel Histogram and Lognormal Distribution.

The app[illegible]
to be
[illegible]
not
logn[illegible]

As discussed earlier, raw coal slag media may contain heavy metals, which contribute to the metal content of this waste stream. Figure 2-6 compares the concentrations of metals in the raw and used media.

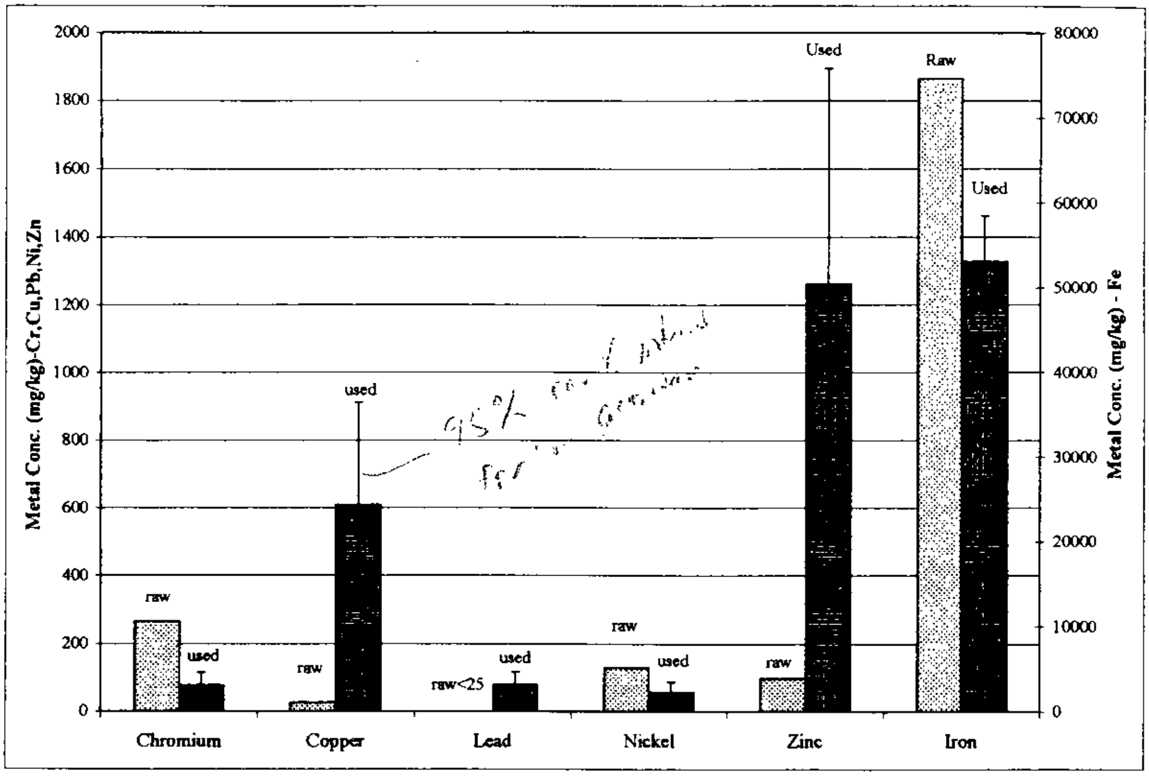


Figure 2-6. Comparison of Raw and Used Media

A 95% confidence interval was constructed for each geometric mean for the used data. The raw media data fell outside the confidence intervals. The bar graph shows that most of the copper, zinc, and lead come from the use of the media while the chromium, nickel, and iron concentrations may come from the unused coal slag media. The raw media can be extremely variable (Townsend and Carlson, 1998) and users should take care to obtain this media from a reliable supplier.

[illegible]

SPLP Leaching

The SPLP test was performed on all samples collected to assess the potential impact of the waste on groundwater. Table 2-6 lists the leachable metal content of the ABM samples for the SPLP test.

do you have a table showing total analysis for unused media? would be useful.

The federal risk-based Soil Screening Guidelines were exceeded for two metals. Sixty-five percent of the samples were above the federal arsenic guideline of 0.4 mg/kg. One sample exceeded the 400 mg/kg guideline for lead, however the arithmetic and geometric mean were below this limit. Metals in the Florida Soil Cleanup Goals were not exceeded by any samples except for arsenic. Sixty-five percent of the samples were above the 0.8 mg/kg residential limit and two samples (9%) were over the industrial limit of 3.1 mg/kg. This waste material is in industrial areas and unless moved or used somewhere else, the industrial soil cleanup goals would apply. The unused media did not exceed the industrial goal for arsenic but did exceed the residential goal. Both the arithmetic and geometric mean for the arsenic data were below the industrial Florida Soil Cleanup Goal. Many states have similar or stricter guidelines, and all local regulations apply to the management of this waste.

3.7

would conclusion change using 3.7 mg/kg

Suggest using upper 95% conf limit

Risk to Groundwater SPLP Tests

The drinking water standards used as groundwater guidance concentrations are regulations that can be enforced by federal and state agencies. In this study, one sample out of 22 exceeded a primary drinking water standard. The sample exceeded the 0.15 mg/L limit for lead at 0.41 mg/L. Both the arithmetic and geometric mean of the lead data were under the primary standard. Three metals were exceeded for secondary drinking waste limits in other samples. Samples exceeded the 10. Mg/L and the 0.3 mg/L limits for copper and iron, respectively. Neither the arithmetic nor geometric mean for copper or iron exceeded the secondary standards. Half of the samples, as well as both the geo metric and arithmetic mean exceeded the 5.0 mg/L limit for zinc.

lead hit in 1 sample.

3 hits for secondary stds.

copper
iron
zinc

typo 1.0 not 10.

This is consistant with lysimeter [illegible]

SPLP

Table 2-6. Leachable Metal Content in Waste ABM (mg/L).

	As^2	Cd	Cr	Cu	Fe	Pb	Ni	Se^2	Zn
No. of Samples	3	22	22	22	22	22	22	3	22
Detection Limit		0.001	0.100	0.200	0.100	0.010	0.100	0.010	0.100
% Detects		74%	0%	95.4%	59%	26%	0%	0%	100%
Minimum		<.001	N/A	<0.2	<0.1	<.010	N/A	N/A	0.81
Maximum		0.002	N/A	2.91	0.71	0.041	N/A	N/A	26.97
Geo. Mean[1]		0.001	N/A	0.72	0.16	0.006	N/A	N/A	5.84
Geo. Std. Dev.		0.001	N/A	0.46	0.17	0.008	N/A	N/A	1.28
Arith. Mean[1]		0.001	N/A	1.00	0.25	0.008	N/A	N/A	8.92
Arith. Stnd. Dev.		.0001	N/A	0.83	0.21	0.008	N/A	N/A	7.67
Prim. MCL		0.005	0.1			0.015	0.1		
Sec. MCL				1.0	0.3				5.0

[1] Average calculated by using ½ the detection limit for undetected samples
[2] Analysis on composite sample from each site

Discussion

Hazardous Characteristic

Waste ABM is not a listed hazardous waste and does not normally exhibit the characteristics of corrosivity, reactivity, and ignitability. The hazardous waste characteristic that ABM may possess is toxicity. The TCLP test was used to test for this characteristic. The composite sample from each site tested below the TCLP limits for the eight heavy metals listed in 40 CFR 261. These results show that the samples collected are not hazardous for the toxicity characteristic.

Direct Human Exposure

The total metal concentrations of the waste ABM samples were compared to the EPA SSLs and the Florida Soil Cleanup Goals. As discussed previously, these goals are tools for assessing the contamination or cleanliness of soil. Further investigation of a site or monitoring may be suggested for a site that exceeded risk-based limits.

The U.S. EPA leaching based SSLs are based on the theoretical leaching model discussed previously for soils. Because waste ABM possesses soil-like characteristics, this model was applied. These numbers are an indication of a potential leaching concern for soils with these total metal concentrations. The leaching based SSL for chromium of 38mg/kg was exceeded by 100% of the waste ABM samples. None of the other leaching based SSLs were exceeded. However, none of the SPLP samples actually leached above the drinking water standard for chromium even though they exceeded the leaching based SSL total metal concentration. This may indicate that the waste ABM possesses different leaching mechanisms than the ones used to calculate the theoretical leaching model. Table 2-7 is a summary of the leaching limit (batch and theoretical) and which samples exceeded the respective limits

Table 2-7. Summary of Leaching Limits and Comparative Results.

	As	**Cd**	**Cr**	**Cu**	**Fe**	**Pb**	**Ni**	**Se**	**Zn**
Prim. DWS (mg/L)	.05	.005	0.1	-	-	0.015	0.1	.05	-
Secd. DWS (mg/L)	-	-	-	1.0	0.3	-	-	-	5.0
SSL-Leach (mg/kg)	29	8	38	N/A	N/A	N/A	130	5	12,000
No. above Prim.	0	0	0	-	-	(1)	0	0	-
No. above Secd.	-	-	-	(8)	7	-	-	-	11
No. above SSL	0	0	22	-	-	-	0	0	0

$\frac{8}{22}$ = 36% $\frac{7}{22}$ = 32% $\frac{1}{22}$ = 5% [illegible]

typo

Correlation of Data

As proof of some correlation between total metal content ~~an~~ and leachable metal content, the same sample that was highest for lead was the same sample which exceeded the primary drinking water standard. To investigate leaching characteristics further, a correlation test was performed on the samples exhibiting leaching behavior. Figures 2-7 and 2-8 show the relationship and correlation between total metal and leachable metal concentrations for zinc and copper. The correlation coefficients were 0.82 and 0.72 for zinc and copper respectively. There is some scatter in the correlation suggesting the leaching mechanisms of this waste stream are complex and not always predictable. A similar correlation for iron produced a correlation coefficient of less than 0.1. This indicates the leaching variability of metals, and that each metal may behave in a different manner.

The batch tests may not be a correct representation of what will actually occur in the environment, but they do give some indication as to the leachability of waste ABM. The range of percent leaching (of total metal concentration) for zinc was 1.5-18.6%. The range of percent leaching for copper was <0.8-9.3%. The percent leaching for iron was much lower than zinc or copper and ranged from <0.004-0.03%.

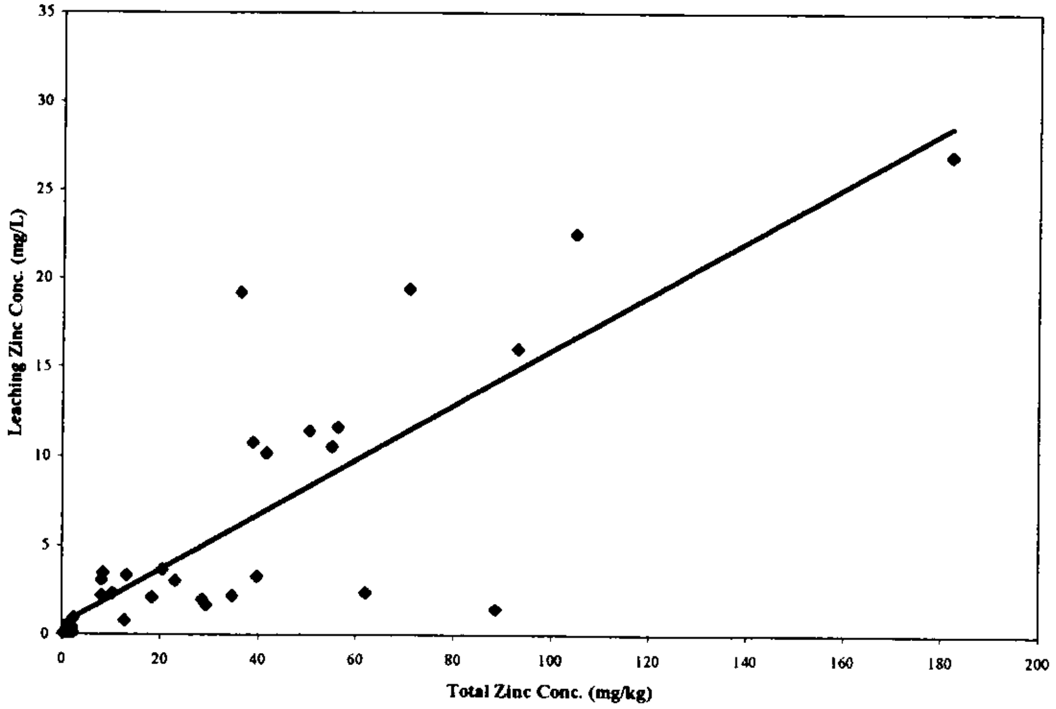


Figure 2-7. Correlation of Leachable and Total Metals for Zinc

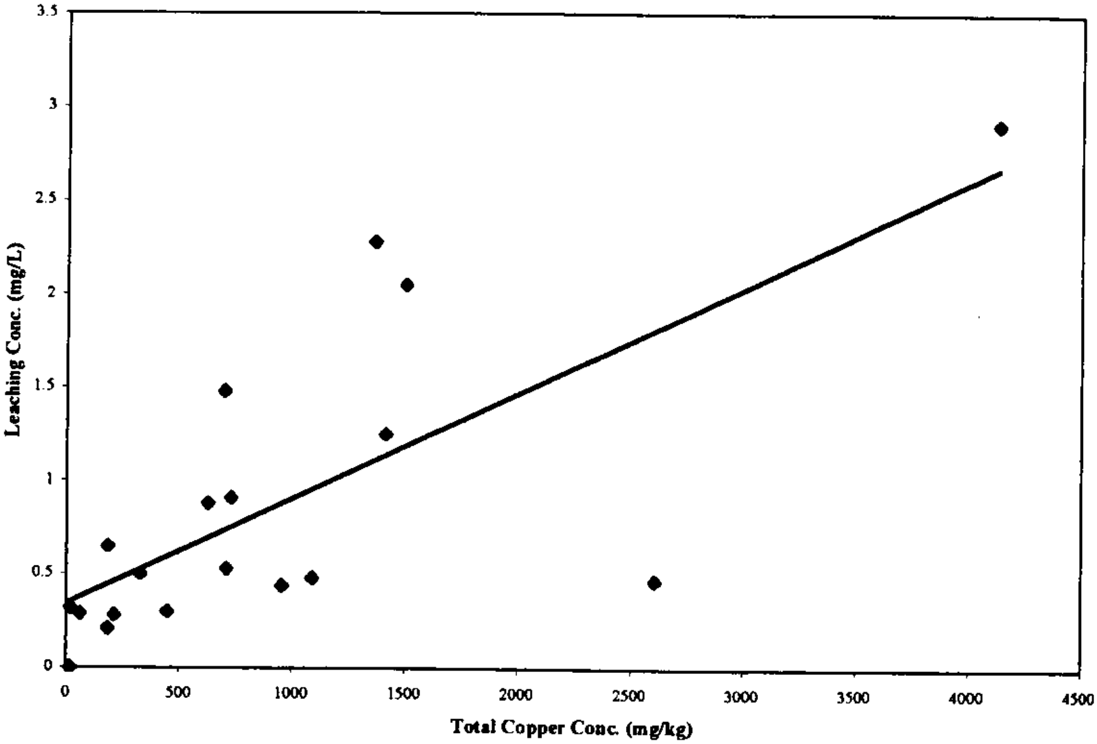


Figure 2-8. Correlation of Leaching and Total Metals for Copper

Implication for Management

The concern over the management of this waste stream is relatively new. In the past, this waste was many times left on site or allowed to fall into the water. With knowledge of environmental impacts and regulatory standards increasing, the management of this waste stream can become complicated and costly.

The abrasive blasting media itself has some metal concentration and then the paint removed with this media creates higher concentrations for some metals. Typically those metals are the one used as pigments, anti-corrosives, and biocides in marine paint. Many ship maintenance facilities have knowledge of the process they use and are typically blasting ships that they painted. The facilities are then aware of the metals in the paint and need to know how to best manage the waste stream created by the blasting process. If an unknown ship is blasted, the paint/coating may be tested first to see which metals may be of concern in the waste stream.

When a non-hazardous waste is produced it typically may go to a lined municipal solid waste facility or other comparable facility. Disposal at a landfill can be costly and other less costly options have been considered. Recycling operations are available for abrasive blasting waste. A promising recycling process is in use by two of the maintenance facilities sampled for this study. These facilities recycle the waste produced in a cement kiln. The coal slag contains ingredients used a feedstock for the production of portland cement. Other recycling options include use as aggregate in asphalt or concrete (Townsend and Carlson, 1997). ok

The results of the research of these three ship maintenance facilities indicate that this waste stream has the potential to exceed secondary drinking water standards. This waste would typically not be allowed to be disposed of on-site unless a permit is issued. If stockpiling the waste is needed before transportation to a disposal or recycling facility, care must be taken to not pollute the site if contaminants are known or suspected in the used media. Leachate must be controlled and minimized during the storage of this waste.

agree

may want to state lead is the concern of blasting lead paints [illegible]

typo

Conclusions

The abrasive blasting waste generated by the ship maintenance facilities in this study was non-hazardous. For the most part, the total heavy metal concentration does not pose a threat to human health for direct exposure in an industry setting, with the exception of an occasional arsenic and lead sample. The lead in this waste stream should also be decreasing as lead pigments in paints are phased out. The chromium SSL for leaching was exceeded by all of the samples, however, chromium did not leach above drinking water standards when extracted with both the TCLP and SPLP tests.

Other leaching concerns would be an occasional lead sample for primary drinking water standards. A few metals exceeded secondary drinking water standards (Cu, Fe, Zn) and so this waste must be managed in a way to minimize leachate. In most situations, this waste could not be disposed of in an unlined landfill because it exceeds secondary drinking water standards. Many states classify ABM type wastes as "special wastes" to be handled a little differently than regular wastes. Local regulations should always be reviewed to determine what management options are available to the generator.

agree

CHAPTER 3
CHARACTERISTICS OF WASTE ABRASIVE BLASTING MEDIA FROM SANDBLASTING CONTRACTORS

Introduction

Abrasive blasting is a practical form of paint removal with many applications. Sandblasting contractors are hired by individuals who need a surface cleaned and prepared for painting through abrasive blasting, but do not have the capability to do it themselves. The process of abrasive blasting, commonly called sandblasting among contractors, relies on a high-pressure spray of abrasive media at a surface to remove any unwanted materials from it. The spent media falls to the ground and is a solid waste that includes the material removed from the surface blasted. Many times this waste product is allowed to accumulate on site. The soil-like appearance of this material facilitates this activity. These blasting operations are typically small operations with an extremely variable waste stream.

As with any solid waste, abrasive blasting media (ABM), or sandblast grit waste must be properly stored and managed to minimize impact on human health and the environment. A main concern with waste ABM is the metal content of the waste attributed to the paint and coatings removed from surfaces. A waste pile could cause a potential threat through direct exposure or through leachate produced when it rains. This chapter reports the results of research conducted to address the issues impacting the storage and management of this waste ABM from sandblasting contractors.

The research conducted for this study will benefit the abrasive blasting industry and others with similar waste and storage problems. This study characterizes three separate sandblasting contractor sites and though the results do not apply universally to every sandblast site, but give an indication of the impact this waste stream may have on human health and the environment. The data from these sites may also assist in the decision making process for proper management if this waste stream. This decision making process has been outlined previously (Carlson and Townsend, 1998) and will be used as the format for presenting the discussion of this chapter.

Background

Sandblasting

Sandblasting contractors typically utilize silica sand media. Although this media has been known to cause health problems in the past, with the proper worker and air protection, it is still the best all-purpose and most economical media (Addison, 1997). All of the sites studied in this research utilized silica sand. Other sandblasting media include coal slag, garnet, plastic, glass bead, steel shot/grit, and crushed walnut shells. Specific types of ABM are used for different processes depending on the media characteristics. These characteristics also dictate the options for reuse and recyclability of the spent media (Townsend and Carlson, 1997).

Sandblasting is used for a multitude of applications. Industries which create the largest amount of waste ABM include the ship maintenance industry, Department of Transportation (DOT), and the military (Townsend and Carlson, 1997). These industries blast many of the same items repeatedly and are familiar with the content of coatings removed. A sandblasting contractor may not produce as much waste as these industries, but the waste is more likely to be variable and managed incorrectly. Table 3-1 contains some of the common applications for sandblasting and the industry that would typically provide the service.

Table 3-1. Applications of Sandblasting/Abrasive Blasting Media

APPLICATION	INDUSTRY
Military ships and airplanes	Military (usually Navy)
Bridges	DOT (may sub-contract but still oversees mgmt.)
Ships/Barges	Ship Maintenance Facilities/Marinas
Airplanes/parts	Airplane Maintenance Facility
Autos	Auto Body Shops
Semi-trailers	Sandblasting Contractor
Scaffolding	Sandblasting Contractor
Heavy Machinery	Sandblasting Contractor
Water tanks/towers	Sandblasting Contractor
Railroad Cars	Sandblasting Contractor/Rail Facility

Pigments in Paint

Concern at sandblasting sites would be any metals used as a pigments or additives in the paints removed. Coatings and paint contain various constituents, including binders, solvents, additives, primary pigments, and extenders. Many of these constituents may be either organic or inorganic. Typically the organic components are the binders and solvents, but additives, pigments and extenders may also be synthetic organic compounds. The inorganic components, usually composed of a metallic compound, are commonly primary pigments, additives, and extenders (Lambourne, 1987).

The principal pigment in use is titanium dioxide, which is a white pigment made popular because of fashion concerns. In the past, a common pigment was lead silicate or sulfate, because other metals were used as additives, not pigments (Lambourne, 1987).

The toxicity of this metal has required the phasing out of the use of lead for many applications (Stoffer, 1997). However, lead contaminated ABM waste may still be encountered if an older coating is removed from a surface. Other highly toxic pigments including cadmium and chromium are normally used in specific industrial applications where needed and are being phased out of more general use (Lambourne, 1987). Paints may also contain additives for anti-corrosion to prolong the life of the coating. The metallic compounds for pigments and the anti-corrosion agents may be different or the pigment may act in a dual manner to satisfy both components (Lambourne, 1987). Table 3-2 lists common pigments used in paint and their respective colors as well as their levels of anti-corrosivity.

Table 3-2. Application of Metals in Coatings.

Metal	**Pigment Color**	**Anti-corrosive**
Cadmium	Orange, Yellow, Red	Good (Red Compounds)
Chromium	Orange, Yellow, Green	Good (Green Compounds)
Copper	Red	Good
Iron	Blue, Yellow, Red, Black, Brown	Good
Lead	White, Red, Blue	Good
Nickel	Yellow	Good
Zinc	White, Yellow	Excellent

Regulation

A number of regulatory issues must be addressed in regard to the management of any solid waste, including waste ABM. Federal regulations require a generator to characterize waste produced as hazardous or non-hazardous. A hazardous waste must be managed according to the Code of Federal Regulations. Waste ABM is not a listed hazardous waste and the characteristic most encountered to classify the waste as hazardous is toxicity.

Hazardous characteristic

The toxicity characteristic leaching procedure (TCLP) test is the assay prescribed by the EPA to determine whether a solid waste is hazardous by toxicity characteristics (40 CFR 261). In this test, a solid waste is extracted using an acetic acid based solution, with a pH that is dependent on the buffering capacity of the waste. The leaching solution is designed to simulate anaerobic conditions within a landfill. TCLP leachate concentration limits have been established for a number of metals and organic compounds. If the leachate concentration from a waste is at or above these limits, it is hazardous. Past research has indicated that organic compounds are not usually encountered when dealing with waste ABM (Townsend and Carlson, 1997).

Direct human exposure limits

A non-hazardous waste is still a solid waste and is subject to state and federal regulation. When waste is allowed to accumulate on-site, as ABM typically is, it may be subject to direct exposure and groundwater contamination limits. Once a waste has been found to be non-hazardous, other analytical assessments may be made. The total metal concentration is a measure of the total amount of metal in a solid sample of the waste ABM. This metal content can be compared to both federal regulations and state direct exposure guidelines as presented in Table 3-3. Direct exposure numbers are set from a risk-based standpoint, but these are goals and not regulations. The U.S. Environmental Protection Agency has published a Soil Screening Guidance Document with limits (SSLs) for many contaminants based on a risk-associated calculation. When the SSLs are

why didn't you say something similar in Chap. 2? (p. 9) exceeded further investigation is required, but the result does not necessitate cleanup (U.S. EPA, 1995). Many states have their own soil screening, guidance levels, or goals. State limits may be more stringent than the federal limits, requiring further investigation at the state level.

Leaching model limits

Along with the risk-based concentration limit in the SSLs is a leaching concentration limit for total metals. These second set of total metal concentrations were calculated from the drinking water standards with a theoretical leaching model. First, the drinking water standard was multiplied by a dilution/attenuation factor of 20. This factor was selected by a "weight of evidence" approach by EPA. This overall factor accounted for dilution and attenuation in the environment for a 0.5-acre area. A total metal concentration was calculated that would result in the augmented drinking water standard. The model for this calculation incorporated the partition coefficient (K_d) of each compound. Figure 3-1 is the equation used by the U.S. EPA to calculate the total metal concentration from the drinking water standards.

$$C_t = C_w\left(K_d + \frac{\theta_w + \theta_a H'}{\rho_b}\right)$$

Where C_t=screening level in soil (mg/kg)
C_w=target soil leachate concentration (mg/L)
K_d=soil-water partition coefficient (L/kg)
θ_w=water-filled soil porosity (assumed 0.3)
θ_a=air-filled soil porosity (assumed 0.13)
ρ_b=dry soil bulk density (assumed 1.5 kg/L)
H'=dimensionless Henry's Law Constant (H-atm-m^3/mol x 41(C.F.))

Figure 3-1. U.S. EPA Soil Screening Guidance Theoretical Leaching Equation

The EPA recognized that partition coefficients are affected by many situational circumstances, especially for metals. The K_d may be affected by pH, oxidation-reduction potential, iron oxide content, soil organic matter content, cation exchange capacity, and major ion chemistry, among others (U.S. EPA, 1995). Therefore, some actual testing of a contaminated site should follow the theoretical values calculated.

Batch leaching limits

Drinking water limits, often used as groundwater limits, are state and federal regulatory limits that cannot be exceeded. Federal groundwater limits may be supplemented by more stringent and extensive state regulations. Although the TCLP test is primarily used to determine hazardous characteristics, it is sometimes used to determine the potential impact of a waste on groundwater when the waste is stored or disposed in non-landfill conditions. A more suitable test for this scenario is the synthetic precipitation leaching procedure (SPLP). The SPLP assay uses a leaching solution made from nitric and sulfuric acid that simulates acid rain with a pH of 4.20 (sites located east of the Mississippi River). It is the preferred choice by many regulators for determining impacts of waste on groundwater (WDNR, 1997). Other than the leaching solution, which is less aggressive than the TCLP solution to simulate rainfall, all other aspects of the test remain the same as the TCLP test.

Table 3-3 contains primary and secondary federal drinking water standards, as well as the federal generic SSLs (risk-based and leaching) for a number of metals. The Florida soil cleanup goals are included as an example of state ~~regulatory standards~~ (risk-based contaminant guidelines, for both a residential and an industrial setting

See corrections
on Table 2-2
p. 11

Table 3-3. Regulations and Guidelines for metal concentrations.

Metal	Drinking water Primary (ug/L)	Drinking water Secondary (ug/L)	SSLs (mg/kg) Risk	SSLs (mg/kg) Leach.	Residential FSCG (mg/kg)	Industrial FSCG (mg/kg)
As	50	-	0.4	29	0.8	3.1
Ba	2,000	-	5,500	1,600	5,200	84,000
Cd	5	-	78	8	37	600
Cr	100	-	390	38	290	430
Cu	-	1,000	N/A	N/A	N/A	N/A
Fe	-	300	N/A	N/A	N/A	N/A
Pb	15	-	400	N/A	500	1,000
Hg	2	-	23	23	23	480
Ni	100	-	1,600	130	1,500	26,000
Se	50	-	390	5	390	9,900
Ag	-	100	390	34	390	9,000
Zn	-	5,000	23,000	12,000	23,000	560,000

Methodology

Sampling

The samples obtained in this study all came from sandblasting contractor facilities in Central Florida. Two facilities were sampled on the same day (January 8, 1998) and a third was sampled on January 19, 1998. Since metals were the primary pollutants of interest, nitric acid rinsed plastic containers and stainless steel utensils were used.

All samples were collected in 13.2-Liter containers. The containers were used to gather a large sample volume from each sample area to assure a representative sample of that area of the site. The top of each sample area was scraped off and the sample taken from approximately 0.5-1m into the pile. Samples were gathered systematically from a random starting point around the circumference of the piles, and encompassed anywhere from a few weeks to months of compiled media. At sites where the media was spread out over the site, systematic random sampling was used. A random start point was chosen and samples were gathered at set distances from there. All sample areas were recorded and mapped for future reference. Table 3-4 contains descriptions and number of samples collected from each site.

Table 3-4. Sandblasting Contractor Sites Sampled

	Sand Blast Site A	**Sand Blast Site B**	**Sand Blast Site C**
Media	Silica Sand	Silica Sand	Silica Sand
Pile(s) Mass (kg)	91,000 (spread)	900	900
Dimensions (m)	600x600x1	12x6x2	10x6x2
No. of samples	6	4 (19-L container)	5
Area Blasted	Out-doors	Blasting Bay	Out-Doors
Primary Work	Scaffolding/Semis	CAT Equipment	Various

Raw ABM collected

Samples of raw ABM were obtained from the supplier to each general contractor. The samples were taken from 23 Kg bags purchased from Standard Sand and Silica. It was not expected to find metals in the raw silica sand, but the raw samples were treated the same as the used samples and all of the same analyses were performed on these samples.

Sub-sampling

The 13-Liter containers collected at each site were mixed thoroughly in the lab. A sub-sample of 400g was taken from each bucket. Sub-sampling created a smaller volume for analytical analysis and ensured similar sample was used for both total metal and leaching analyses. A composite sample from each site was formed at a later time. This sample was used to determine if the waste was hazardous or not.

Analysis of Waste ABM

The waste ABM was tested for both total metal concentrations and leachable metal concentrations. These metal concentrations are then compared to both state and federal regulatory limits and goals. Two primary leaching methodologies were used, the TCLP (EPA Method 1311) and the SPLP (EPA Method 1312). For both leaching tests, 2 liters of appropriate fluid was added to 100g of the solid material. The solid and liquid was mixed for 18 hours in a rotary extractor, the leachate was filtered, and then preserved and stored according to the parameter of interest (preserved at a pH of <2 for metals).

The methods used for the digestion and analysis of the samples are from the EPA SW-846 manual. Method 3050b was used to digest the solid samples, while 3010 and 3020 were used for the liquid samples for the flame and furnace, respectively. Samples were analyzed on a Perkin Elmer 5100 atomic absorption spectrophotometer equipped with a flame and a furnace.

The metals examined for the samples included the required TCLP metals for the hazardous characteristic (As, Ba, Cd, Cr, Pb, Hg, Se, Ag). The next set of metals included typical metals found in paints and coatings and possibly in the unused media (As, Cd, Cr, Cu, Fe, Pb, Ni, Se, Zn). Total metal analyses were completed first and then the same metals were examined from a leaching standpoint.

Results

The results of the chemical analyses of the ship blast samples are grouped into two areas: the total metal content and the leachable metal content. These two characteristics are compared to both federal and state regulations and guidelines.

TCLP Results

The composite samples from each ship maintenance facility were tested to see if they were hazardous or not. Table 3-5 contains the TCLP limits and results from this study.

Table 3-5. TCLP Limits and Results.

	As	Ba	Cd	Cr	Pb	Hg	Se	Ag
TCLP Limit	**5**	**100**	**1**	**5**	**5**	**0.2**	**1**	**5**
Det. Limit	.001	10	.001	.100	.010	.001	.010	1
Sndblst Site A	BDL	BDL	.001	BDL	.008	BDL	BDL	BDL
Sndblst Site B	BDL	BDL	.015	BDL	.006	BDL	BDL	BDL
Sndblst Site C	BDL	BDL	.009	BDL	.002	BDL	BDL	BDL

*Units mg/L, BDL=Below Detection Limit

Total Metal Results

Table 3-6 contains the total metal concentrations examined for each sample as well as the detection limits, the percent of samples above the detection limit, the range of values found and two different averages and standard deviations for each metal. The distribution of the data can affect the averages and standard deviation of each data set. Typically, these data followed a logarithmic distribution, except for iron; therefore the geometric mean was used for future comparisons. Figures 3-2 through 3-6 present the histograms formed by the data sets as well as the distributions for zinc, lead, chromium, nickel and iron.

Table 3-6. Total Metal Content in Sandblasting Contractor Waste ABM.

(mg/kg)	As	Cd	Cr	Cu	Fe	Pb	Ni	Se	Zn
No. of Samples	15	15	15	15	15	15	15	15	15
Detection Limit	0.05	2.5	5	25	5	25	5	0.5	5
% Detects	27%	0%	100%	0%	100%	67%	100%	0%	100%
Minimum	<.05	N/A	12.6	N/A	826.8	<25	4.78	N/A	24.3
Maximum	.08	N/A	59.1	N/A	2,801	99.5	53.1	N/A	4,328
Geo. Mean[1]	.05	N/A	32.8	N/A	1,300	36.6	13.2	N/A	211.1
Geo. Std. Dev.[1]	.04	N/A	1.56	N/A	1.42	2.26	2.21	N/A	5.83
Arith. Mean[1]	.06	N/A	35.6	N/A	1,380	47.3	18.1	N/A	759.6
Arith. Stnd. Dev.[1]	.04	N/A	13.3	N/A	523	29.4	16.1	N/A	1,173

[1] Calculated with undetected samples at ½ detection limit.

SCTLs	As	Cd	Cr	Cu	Fe	Pb	Ni	Se	Zn
Residential	0.8	75	210	110	23,000	400	110	390	23,000
Industrial	3.7	1300	420	76,000	480,000	920	28,000	10,000	560,000
Leachability	29	8	38	-	-	-	130	5	6000

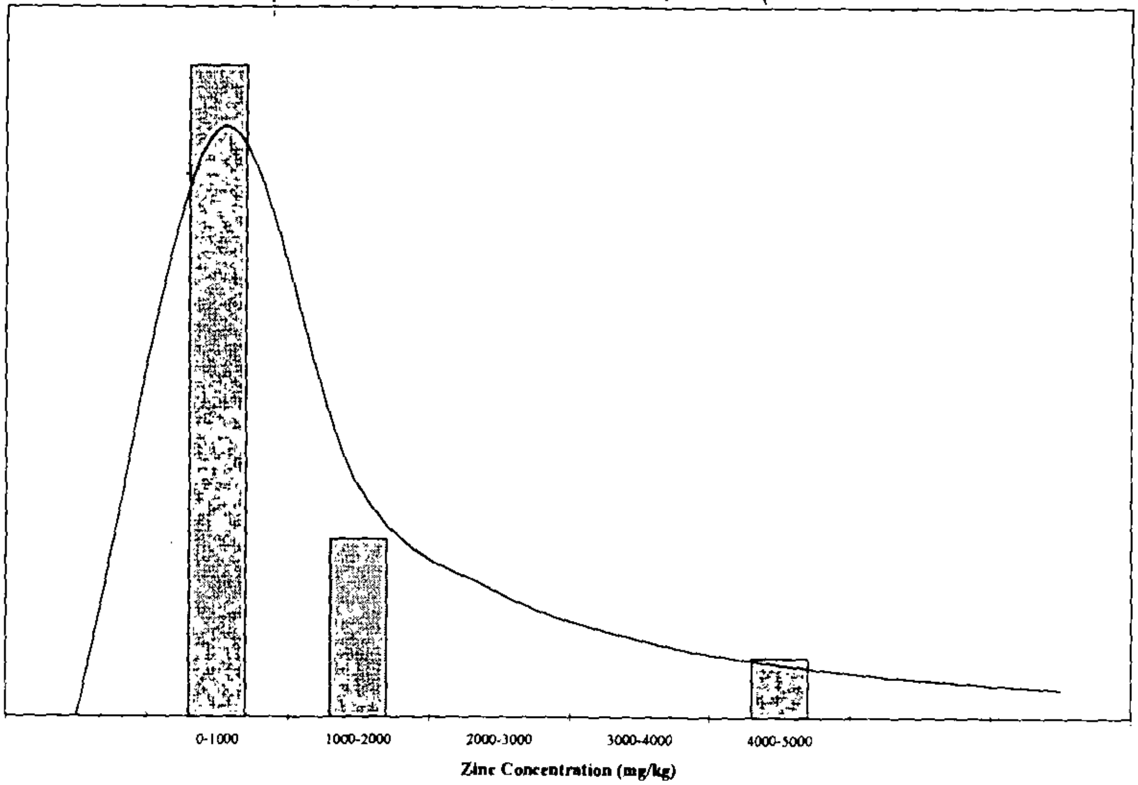


Figure 3-2. Zinc Histogram and Lognormal Distribution.

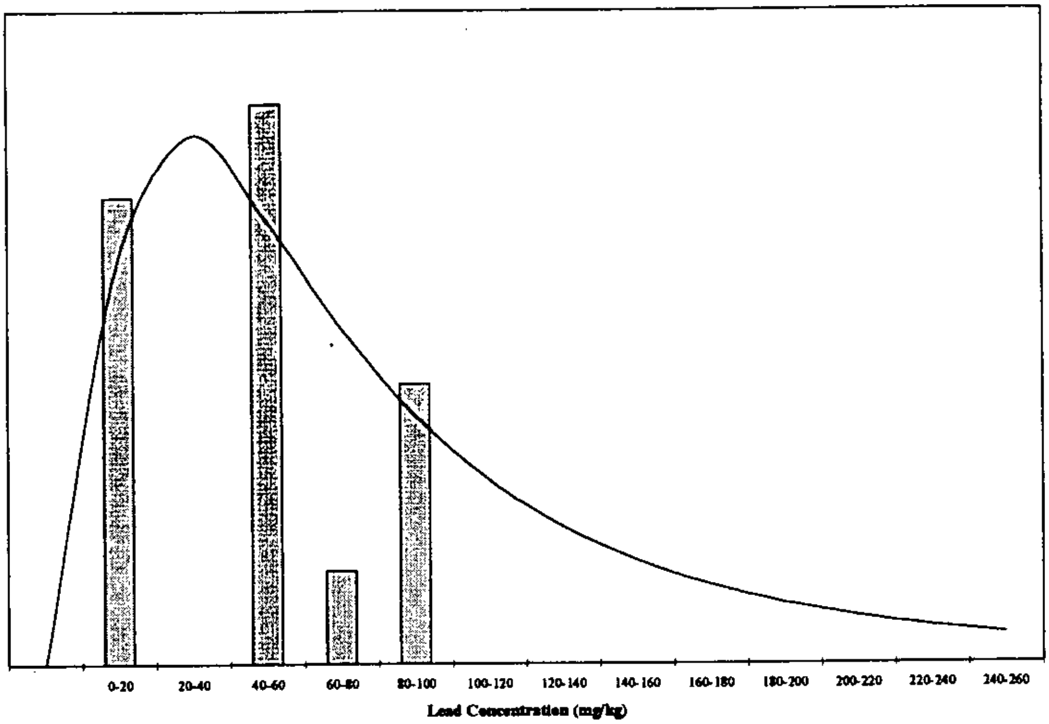


Figure 3-3. Lead Histogram and Lognormal Distribution.

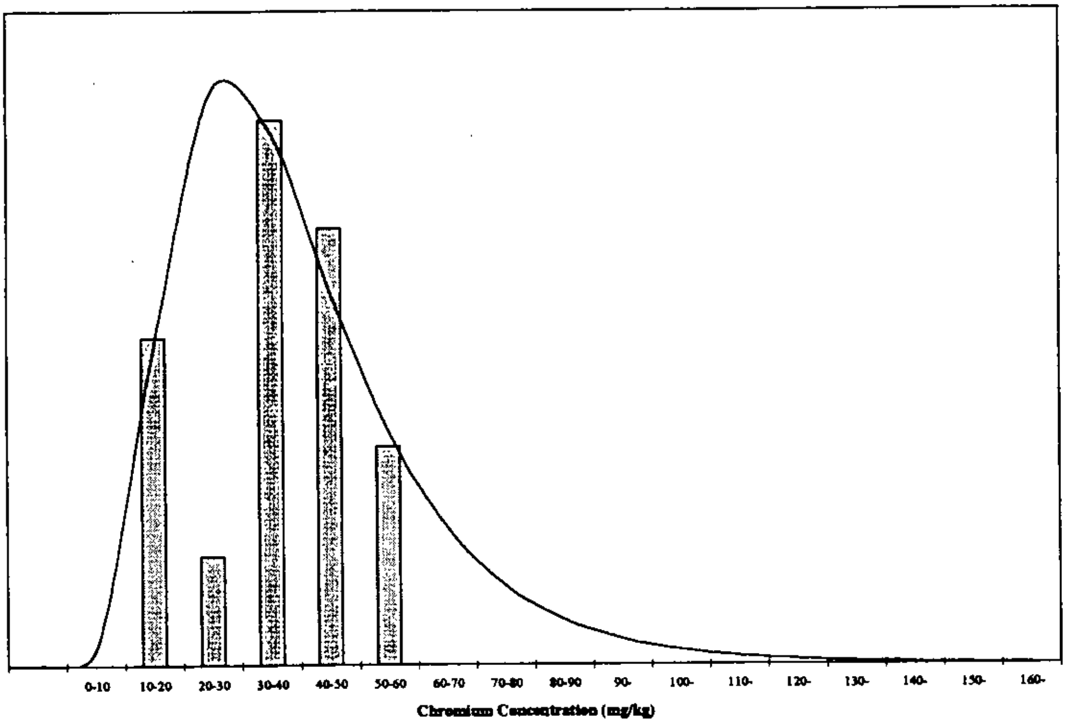


Figure 3-4. Chromium Histogram and Lognormal Distribution.

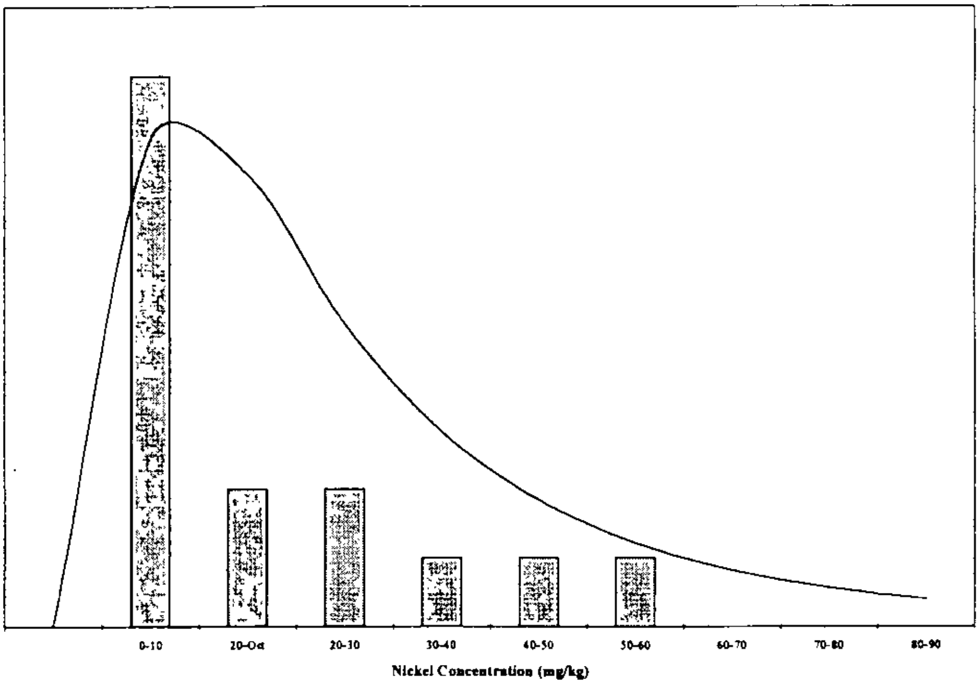


Figure 3-5. Nickel Histogram and Lognormal Distribution.

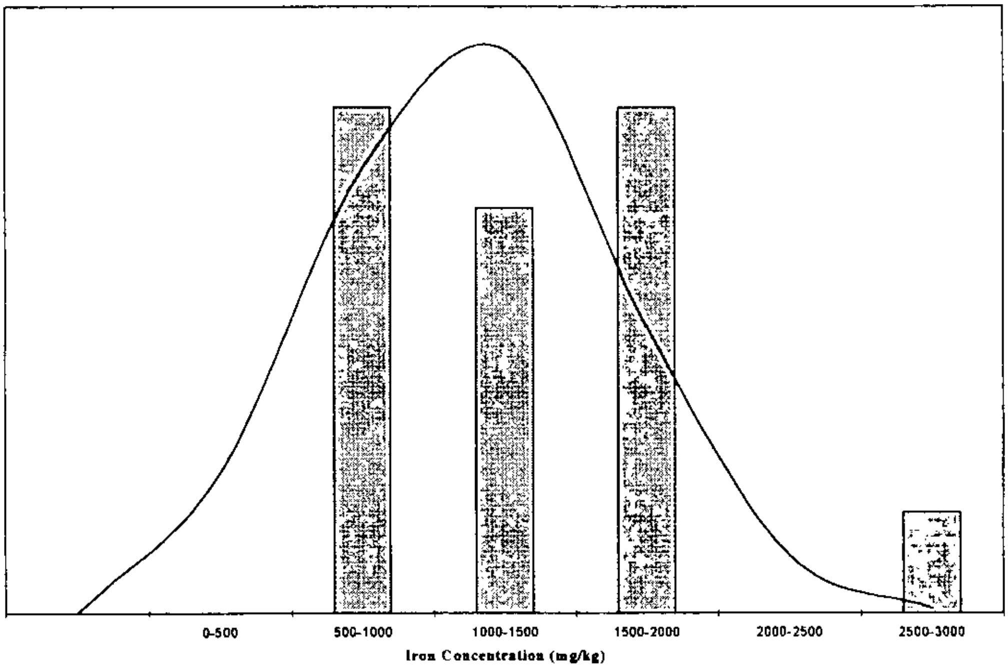


Figure 3-6. Iron Histogram and Normal Distribution.

D/L

Leachable Metal Content

The SPLP test was performed on all samples collected to assess the potential impact of the waste on groundwater. Table 3-7 lists the leachable metal content of the ABM samples for the SPLP test.

Table 3-7 SPLP Leachable Metal Content in Waste ABM (mg/L).

	As[2]	**Cd**	**Cr**	**Cu**	**Fe**	**Pb**	**Ni**	**Se**[2]	**Zn**
No. of Samples	3	15	15	15	15	15	15	3	15
Detection Limit	0.010	0.001	0.100	0.200	0.100	0.010	0.100	0.010	0.100
% Detects	0%	12.5%	0%	0%	94%	0%	0%	0%	40%
Minimum	N/A	<.001	N/A	N/A	<0.1	N/A	N/A	N/A	<0.10
Maximum	N/A	.009	N/A	N/A	1.14	N/A	N/A	N/A	2.56
Geo. Mean[1]	N/A	.001	N/A	N/A	0.25	N/A	N/A	N/A	0.18
Geo. Std. Dev.	N/A	.002	N/A	N/A	0.14	N/A	N/A	N/A	0.63
Arith. Mean[1]	N/A	.002	N/A	N/A	0.31	N/A	N/A	N/A	0.67
Arith. Stnd. Dev.	N/A	.002	N/A	N/A	0.18	N/A	N/A	N/A	0.93
Primary MCL	5	0.005	0.1			0.015	0.1		
Secondary MCL	0.05			1.0	0.3				5.0

[1] calculated by using ½ the detection limit for undetected samples

[2] Analysis on composite sample from each site

Discussion

Hazardous Characteristic

Waste ABM is not a listed hazardous waste and does not normally exhibit the characteristics of corrosivity, reactivity, and ignitability. The hazardous waste characteristic that ABM may possess is toxicity. The TCLP test was used to test for this characteristic. The composite sample from each site tested below the TCLP limits for the eight heavy metals listed in 40 CFR 261. These results show that the samples collected are not hazardous for the toxicity characteristic.

Direct Human Exposure

The total metal concentrations of the waste ABM samples were compared to the EPA SSLs and the Florida Soil Cleanup Goals. As discussed previously, these goals are tools for assessing the contamination or cleanness of soil. Further investigation of a site or monitoring may be suggested for a site that exceeded risk-based limits. No samples exceeded any federal risk-based SSL. None of the samples exceeded the residential or industrial limits of the Florida Soil Cleanup Goals. These sites are in industrial areas and typically the industrial goals would apply. Many states may have similar or stricter guidelines, and all local regulations apply to the management of this waste.

Risk to Groundwater

The drinking water standards used as groundwater guidance concentrations are regulations that can be enforced by federal and state agencies. In this study, one sample out of 15 exceeded a primary drinking water standard. The sample exceeded the 0.005 mg/L limit for cadmium at 0.009 mg/L. Both the arithmetic and geometric mean of the cadmium data were under the primary standard. One metal exceeded secondary drinking water limits in other samples. Seven samples exceeded the 0.3 mg/L limit for iron. The arithmetic mean for iron exceeded the secondary standards by .01 mg/L, however the geometric mean did not exceed the standard. The distribution of iron looks normal and so the arithmetic mean would be applied.

1 primary hit for cadmium

7 secondary hits all for iron

The U.S. EPA leaching based SSLs are based on the theoretical leaching model discussed previously for soils. Because waste ABM possesses soil-like characteristics, this model was applied. These numbers are an indication of a potential leaching concern for soils with these total metal concentrations. The leaching based SSL for chromium of

38mg/kg was exceeded by seven of the waste ABM samples. None of the other leaching based SSLs were exceeded. However, none of the SPLP samples actually leached above the drinking water standard for chromium even though they exceeded the leaching based SSL total metal concentration. This may indicate that the waste ABM possesses different leaching mechanisms than the ones used to calculate the theoretical leaching model. Table 3-8 is a summary of the leaching limit (batch and theoretical) and which samples exceeded the respective limits

Table 3-8. Summary of Leaching Limits and Comparative Results.

	As	**Cd**	**Cr**	**Cu**	**Fe**	**Pb**	**Ni**	**Se**	**Zn**
Prim. DWS (mg/L)	.05	.005	0.1	-	-	0.015	0.1	.05	-
Secd. DWS (mg/L)	-	-	-	1.0	0.3	-	-	-	5.0
SSL-Leach (mg/kg)	29	8	38	N/A	N/A	N/A	130	5	12,000
No. above Prim.	0	1	0	-	-	0	0	0	-
No. above Secd.	-	-	-	0	7	-	-	-	0
No. above SSL	0	0	7	-	-	-	0	0	0

Correlation of Data

These leaching numbers correlate with the total metal data shown earlier. A correlation of total metal amounts and leachability was done for the individual samples above the detection limits. There was no correlation found between the leachable and total metals concentrations (correlation coefficient <0.1). The range of percent leaching (of total metal concentration) was 0.7-13.4% for zinc. The range for percent leaching of iron was <6.3%-53.5%.

Conclusions

Sandblasting contractor waste was non-hazardous from the sites characterized in this study. The sites sampled for this research blasted various equipment from scaffolding to heavy machinery. The concentration of heavy metals in the sandblast grit did not pose direct threat to human health when compared both state and federal risk-based standards. Although the leaching level for chromium was exceeded for the federal SSL, the samples did not leach above the primary drinking water standard when extracted with either TCLP or SPLP.

The secondary drinking water standard for iron is exceeded in the SPLP leachate produced by this waste 46% of the time. Results exceeding this standard could force generators to dispose of this waste in lined landfills. If this waste must be stored on property, care should be taken to minimize the amount of leachate produced.

CHAPTER 4
LEACHING CHARACTERISTICS OF WASTE ABRASIVE BLASTING MEDIA

Introduction

Abrasive blasting removes paint, coatings, and corrosion from primarily metallic surfaces. This blasting process produces a solid waste, which contains the media used to blast as well as any material removed from the surface. This solid waste often contains measurable levels of heavy metals from paints, coatings (pigments and additives) and the blasting media itself. The management of waste abrasive blasting media (ABM) includes discard on-site, landfilling, and recycling. A framework for determining proper management has been previously outlined (Carlson and Townsend, 1998). Consideration must be given to the risk to human health through direct exposure and to the risk of groundwater contamination through chemical leaching.

The largest producers of this waste stream are ship maintenance facilities, military operations, and the transportation departments (steel bridges) (Townsend and Carlson, 1997). The characteristics of waste ABM from military operations and bridge blasting have been investigated to some extent (EPA, 1994, Medford, 1989) because of the potential for this material to be hazardous and the coordinated environmental efforts of these organizations. Waste ABM from operations such as shipyards and sandblasting contractors have received less attention. This results from the smaller nature of these organizations and the greater likelihood for this material to be non-hazardous. However, even a material that is non-hazardous potentially poses a risk to the environment if managed improperly.

This study focuses on the leaching characteristics of waste abrasive blasting media from ship maintenance facilities and sandblasting contractor sites. The general characteristics of these waste streams and their proper management under current regulatory policy has been previously reported in Chapters 2 and 3. These chapters raised concern over waste ABM exceeding some secondary drinking water limits when extracted with the synthetic precipitation leaching procedure. More investigation of the leaching mechanisms was needed to properly address this issue. This chapter analyzes the phenomenon of chemical leaching from waste ABM through column leaching tests to better simulate field conditions, in addition to standardized regulatory leaching tests. The relationship between these tests and the impact of waste ABM chemical leaching on the environment are explained.

Background

Leaching tests have been used for many years to determine what leaches off a material under various conditions. Standardized leaching tests have been developed for regulatory work and site assessment. These standard tests are typically easy to replicate batch leaching tests, however leaching column studies also have been developed to determine the leachability of a waste.

Batch Leaching

The Toxicity Characteristic Leaching Procedure (TCLP) is a batch leaching extraction test prescribed by the U.S. EPA for determination of the toxic characteristic of a hazardous waste (40 CFR 261). In this test, a solid waste is extracted using a leaching fluid for 18 hours. The leaching fluid is an acetic acid based solution, with a pH that is dependent on the buffering capacity of the waste. The leaching solution is designed to simulate anaerobic conditions within a landfill. If a waste is not landfilled, the TCLP may not be an accurate representation of what would happen in the natural environment. A test called the Synthetic Precipitation Leaching Procedure (SPLP) may predict leachate in the environment more accurately. This test is exactly like the TCLP except the extraction fluid is made from dilute nitric and sulfuric acids (simulating rainfall), with a pH 4.2 for sites east of the Mississippi River.

Many other leaching tests have been proposed and used in the past and still may be in use today. These tests include the Monofilled Waste Extraction Procedure (MWEP), U.S. EPA Extraction Procedure (EP replaced by TCLP), Ham Procedure C, Acetate Buffer Extraction Procedure (ABEP), and Saturated Paste Procedure (PASTE), (Jackson and Bisson, 1990). These tests are all batch extraction processes with liquid added to a prescribed amount of solid sample and agitated for a certain amount of time. Some of the tests involve multiple additions of extraction fluid. The extraction fluid is then analyzed for contaminants of concern.

Column Leaching

Leachability of waste can also be assessed in column leaching studies. Column leaching, or lysimeter studies consist of filling a container (often a cylinder) with a particular waste and adding a prescribed amount of extraction fluid to the top of the column and draining the leachate produced from the bottom. There is no proscribed leaching column procedure by the U.S. EPA and there are many variations to this type of study. The method used in this study was developed at the University of Florida and used for other waste studies (Brantley, 1998).

Both of the leaching processes discussed are useful in assessing the leachability of a waste. This study will compare these leaching processes with analytical data. Table 4-1 contains advantages and disadvantages to batch and lysimeter leaching tests.

Table 4-1. Comparison of Batch and Lysimeter Leaching

	ADVANTAGES	DISADVANTAGES
Batch Leaching	Reproducible Simple design Standardized test available	Not field conditions Smaller sample/less representative
Lysimeter Leaching	Larger, more representative sample Better simulates field conditions More freedom in design	Channeling may occur Variable results Difficult to set up

Methodology

The samples gathered for this study were apart of a sampling process done for each separate waste stream. The samples were collected over a two-day sampling trip in January 1998.

Sample Collection

All samples were collected in 13.2-Liter containers. Since metals were the primary pollutants of interest, nitric acid rinsed plastic containers and utensils were used. plastic containers and stainless steel sample utensils were used.

The containers were used to gather a large sample volume from each sample area to assure a representative sample of that area of the pile. The top of each sample area was scraped off and the sample taken from approximately 0.5-1m into pile. Samples were gathered systematically from a random starting point around the circumference of the piles, and encompassed a few weeks of compiled media. All sample areas were recorded and mapped for future reference. Table 4-2 contains descriptions and number of samples collected from each site.

Table 4-2. Ship Maintenance Facilities Sampled

Site	Media	Pile Mass (kg)	Dimensions (m)	No. of samples
Ship Blast A	Coal slag	27,000	12x5x3	12
Ship Blast B	Coal Slag	54,000	18x9x2	6
Sand Blast A	Silica Sand	91,000	600x600x1	6
Sand Blast B	Silica Sand	900	12x6x2	4 (19-L Cont.)

Unused ABM collected

Samples of raw ABM were obtained from the supplier to each site. The samples were taken from 22.7-kg bags purchased from Standard Sand and Silica. As discussed earlier, metals may exist in the raw ABM, which could classify the material as hazardous (very rare) or in which leachate from the raw ABM could cause groundwater contamination problems. The raw samples were treated the same as the used samples and all of the same analyses were performed on these samples.

Batch Leaching Tests

Batch leaching tests were performed on each sample that went into the lysimeters. A toxicity characteristic leaching procedure (TCLP) test was done as well as the synthetic precipitation leaching procedure (SPLP). These batch leaching test results could then be compared to the lysimeter leachate formed.

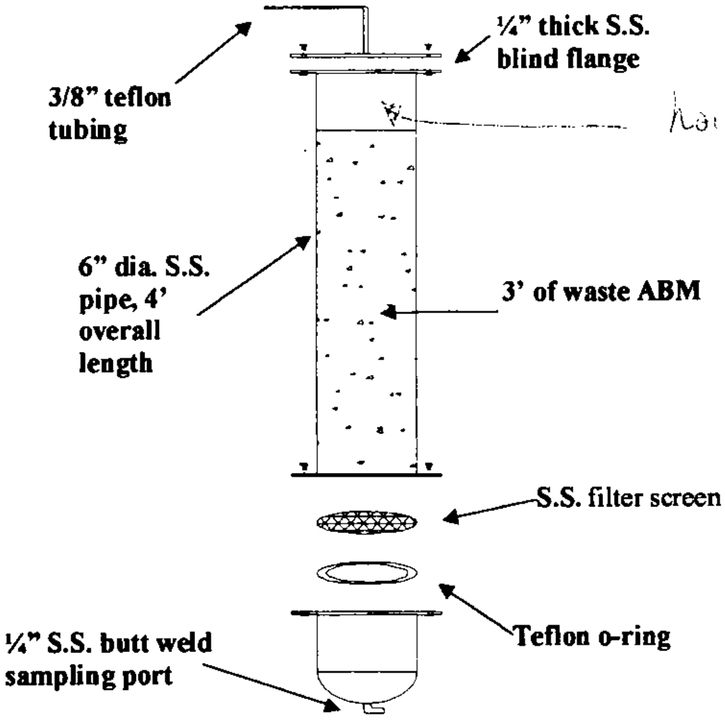
For both the TCLP and SPLP, the waste sample is size-reduced to a particle size below 9.5mm, and added to a leaching solution at a 20:1 liquid to solid ratio. The solid and liquid is mixed for 18 hours in a rotary extractor, the leachate is filtered, and then preserved and stored according to the parameter of interest (preserved at a pH of <2 for metals).

Lysimeters

Leaching columns, commonly called lysimeters, were filled with each site's waste stream. Two columns were also filled with the raw media to obtain background metal concentrations. A blank column, with only the drainage material was also used in the experiment to make sure no contamination came from the gravel used as drainage material. Figure 4-1 is a diagram of the filled lysimeter.

Filling process

The lysimeters were filled starting from the bottom with a stainless steel screen followed by acid rinsed gravel. This process was repeated three times and then the waste (approximately 1m) was placed on top. The gravel served as drainage material for the leachate so that it did not sit in the waste stream after it filtered through the material. The lysimeters are approximately 1.2m tall and 15cm in diameter.



how do you distribute leachate at the top of the lysimeter?

Figure 4-1. Diagram of Lysimeter Apparatus (Brantley, 1998)

The lysimeters are made of all stainless steel and Teflon tubing. The waste was loaded by creating a composite sample from each site and loading them into each column. Composite samples were formed by mixing a bowl full of waste from each sample container. These bowls were weighed separately and the total weight of each lysimeter recorded. Table 4-3 contains the lysimeter number and the type of sample contained in each. Sub-samples of approximately 300g were taken from the waste as it was loaded into the columns. These sub-samples were utilized for other tests including total metal analyses.

Table 4-3 Lysimeter Sample Information

Lysimeter	Site	Sample	Sample Wt. (kg)	Bulk Density (kg/m^3)
1	SM-A	Coal Slag (Ship)	26	1477
2	SM-ADuplicate	Coal Slag (Ship)	27	1495
3	SC-B	Silica Sand	28	1591
4	SM-B	Coal Slag (Ship)	26	1369
5	SC-A	Silica Sand	31	1716
6	Unused	Raw Coal Slag	28	1591
7	Unused	Raw Silica Sand	29	1627
8	Control Blank	-	N/A	N/A

SM=Ship Maintenance Facility, SC=Sandblasting Contractor

Lysimeter leaching

Rainfall conditions were simulated in the lysimeter by discharging 1 liter of SPLP solution, with a pH of 4.2 into the lysimeter every other day. The leachate was added at a rate of 50ml per minute, which is equivalent to 5 cm of rainfall over the surface area of the waste. Every other day before the new SPLP solution was added, the leachate produced was drained. The volume of leachate was recorded and general parameters of the leachate were measured at this time. These parameters included pH, conductivity, oxygen reduction potential and dissolved oxygen. Portions of unpreserved leachate were saved for total dissolved solids, alkalinity, and anion analysis. Another portion was preserved for metal analysis with nitric acid. And a third potion was preserved with sulfuric acid for nonpurgible organic carbon (NPOC), and cation analysis.

how distributed

Results

A number of results were recorded for each composite sample. The results included a total metal analysis, batch-leaching study, and the six-week simulated leaching process. The total metal analysis and batch leaching study were performed on the composite sub-samples taken when the lysimeters were filled.

Composite Sample Analyses

The batch tests included both the SPLP and TCLP test. The sample taken from each site was non-hazardous for the 8 metals in 40 CFR 261 (arsenic, barium, cadmium, chromium, lead, mercury, silver, and selenium). The TCLP extract was also tested for copper, iron, nickel, and zinc. The SPLP extract analyses included the same metals, except for silver. Tables 4-4 through 4-6 are a summary of each lysimeter batch characteristics including total metal concentration, TCLP and SPLP Leaching.

The total metals found in the lysimeter samples are common metals that are found in paint and coal slag media. Lysimeters 1, 2, and 4 have similar characteristics because they are all ship maintenance used coal slag media. The similar characteristics of the unused coal slag media (Lysimeter 6) compared to the used media indicate that some of the metals (As, Cr, Ni) are inherent to the media and other metals (Cu, Zn, Pb) come more from the blasting residuals. The sandblasting contractor samples (Lysimeters 3 and 5) are similar except lysimeter 3 has more iron and lysimeter 5 has more zinc. The unused silica sand media contains no metals above detection limits except for a small amount of mercury and some iron.

The leaching concentrations of the samples vary somewhat, indicating that complex leaching mechanisms are involved in the batch processes. Lysimeter 1 and 2 duplicate well for some metals (Zn, Cu) but not as well for others (Fe). For TCLP tests, Lysimeter 4 leached the most copper and lead, lysimeter 6 leached the most iron and nickel, and lysimeter 5 leached the most zinc. For the SPLP results lysimeter 3 leached the most iron and lysimeter 5 leached the most zinc.

ship shp ship [illegible]

Table 4-4. Total Metal Concentration for each Comp. Sample (mg/Kg).

Metal	L1	L2	L3	L4	L5	L6	L7
As	1.99	2.38	0.1	1.92	<0.5	2.36	<0.5
Cd	<2.5	<2.5	<2.5	<2.5	<2.5	<2.5	<2.5
Cr	98.57	114.5	49.0	133.6	48.10	265.2	<5
Cu	1,910	1,125	<25	3,336	<25	28.10	<25
Fe	80,810	72,500	3,164	62,682	2,080	74,571	168.95
Pb	26.67	23.0	37.0	67.27	<20	<20	<20
Ni	59.05	68.5	12.0	56.36	12.38	129.52	<5
Hg	.004	.004	.002	.001	.002	.003	.001
Se	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Zn	1,464	1,523	104.5	1,623	1,145	98.62	<5

Table 4-5. TCLP Metal Concentration for each Comp. Sample (mg/L).

Metal	L1	L2	L3	L4	L5	L6	L7
As	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Cd	0.004	0.004	0.015	0.004	0.001	<0.001	<0.001
Cr	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100
Cu	17.5	20.0	<0.5	27.9	<0.5	<0.5	<0.5
Fe	5.58	1.54	4.97	1.47	<0.1	21.13	<0.1
Pb	0.103	0.080	0.062	0.171	0.084	<0.010	<0.010
Ni	<0.100	<0.100	<0.100	<0.100	<0.100	0.280	<0.100
Hg	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001
Se	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Zn	62.6	57.9	26.4	58.8	81.0	0.100	<0.100

Table 4-6. SPLP Metal Concentration for each Comp. Sample (mg/L).

Metal	L1	L2	L3	L4	L5	L6	L7
As	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Cd	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Cr	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100
Cu	<0.500	<0.500	<0.500	<0.500	<0.500	<0.500	<0.500
Fe	0.42	0.68	0.70	0.50	0.41	0.61	0.44
Pb	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Ni	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100
Hg	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001
Se	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Zn	1.68	2.63	0.25	1.07	1.81	<0.100	<0.100

Lysimeter Analyses

The first characteristics of interest for the lysimeters are the general parameters. These parameters can give some idea of what kind of processes are occurring inside the lysimeters and what type of conditions the waste was exposed to.

General Water Quality Parameters

Table 4-7 contains the number of readings, the range found, and the averages for many general parameters. Some of the parameters (pH, Conductivity, and NPOC) expressed trends that will be examined further. The pH is an important parameter that can affect the leachability of many substances as well as metal speciation. Figure 4-2 is the plot of pH for the lysimeters. Buffer capacity is the ability of a substance to resist pH change with the addition of a strong acid or base.

? X

Table 4-7. General Parameters for Lysimeters

	L1	L2	L3	L4	L5	L6	L7	L8
No. Collected	20	20	20	20	20	20	20	20
Avg. DO[1]	6.61	6.11	2.67	6.39	4.65	6.88	8.56	8.50
Max	8.03	7.07	6.05	7.5	5.63	8.54	9.08	8.8
Min	4.67	4.86	1.5	5.31	3.27	4.54	8.00	7.9
Avg. ORP	481.3	480.6	181.4	464.5	539.6	563.5	599.0	614.8
Max	548	547	568	577	588	615	649	658
Min	227	226	-133	194	400	430	507	558
Avg. pH	7.20	7.15	7.03	7.22	7.00	5.96	4.36	4.04
Max	7.35	7.29	7.38	7.44	7.12	7.54	5.04	4.30
Min	6.90	6.94	6.67	6.12	6.84	2.88	2.97	3.16
Avg.TDS[1]	476	404	513	518	238	91	61	48
Max	980	980	1830	1340	1320	400	360	180
Min	160	120	280	280	60	0	0	0
Avg. Conduct.[2]	729	672	685	785	248	146	106	55
Max	1551	1265	1494	1850	344	985	782	464
Min	428	512	525	494	205	41	23	16
Avg. NPOC[1]	9.81	6.0	50	11	5.0	0	1	0
Max	23.1	18.0	341	32.5	34.7	0.999	2.44	1.26
Min	5.19	4.05	18.9	7.75	2.13	0.06	0.124	0
Avg. Alk.[3]	321	291	273	280	118	1	0	0
Max	449	375	320	370	131	3	0	0
Min	210	250	246	230	106	1	0	0

[1] Units in mg/L

[2] Units in uS

[3] Units in mg/L as $CaCO_3$

Other pH buffers include metal ions and oxidation reduction potential buffers (Snoeyink and Jenkins) and ions like carbonate contribute to the buffering capacity. Lysimeters 1 through 5 had some buffering capacity as they brought the pH of the fluid up to approximately 7. Lysimeter 6 (raw coal slag) also had buffering capacity, but expressed it at a slower rate. Lysimeter 7 (raw silica sand) had little buffering capacity expressed late. As expected, the SPLP fluid did not change pH in the control lysimeter.

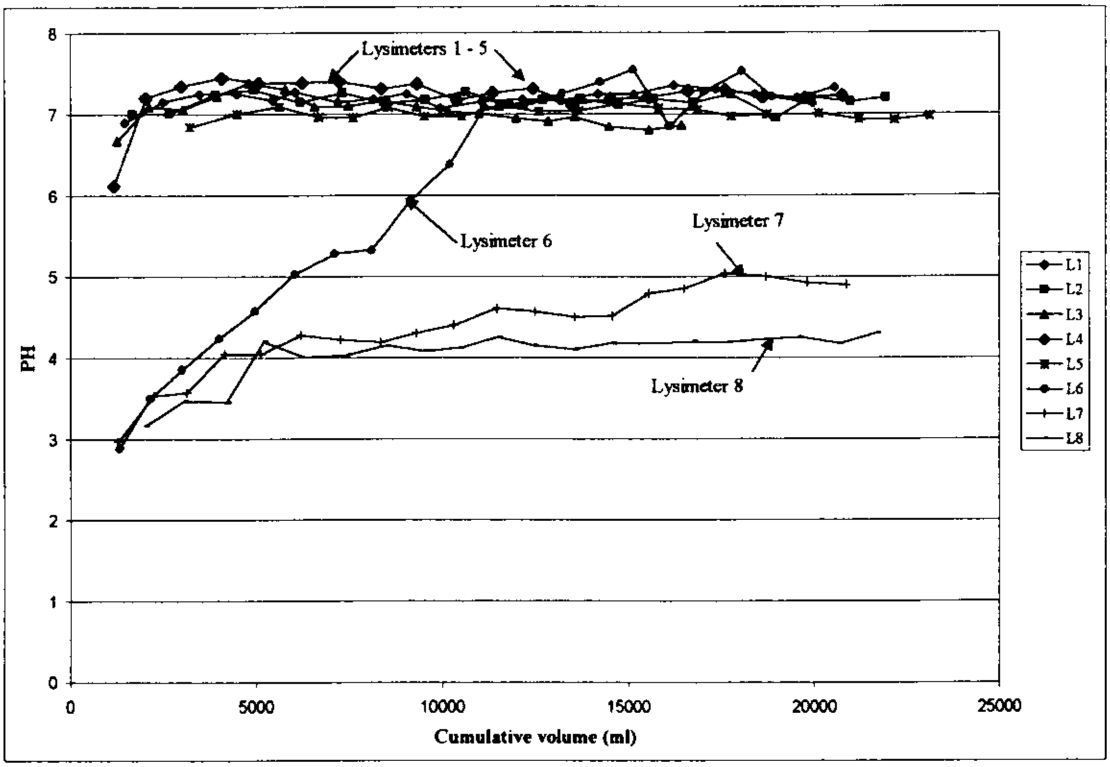


Figure 4-2. Lysimeter pH graph.

The DO level may indicate whether biological reactions are occurring in the lysimeters. From Table 4-7 DO data, Lysimeter 3 is the only lysimeter with some potential biological activity. This data is confirmed by the nonpurgible organic carbon data following. There was little organic carbon in these lysimeters except for lysimeter 3. The graph of the nonpurgible organic carbon follows a typical leaching curve for lysimeter 3 (Figure 4-3).

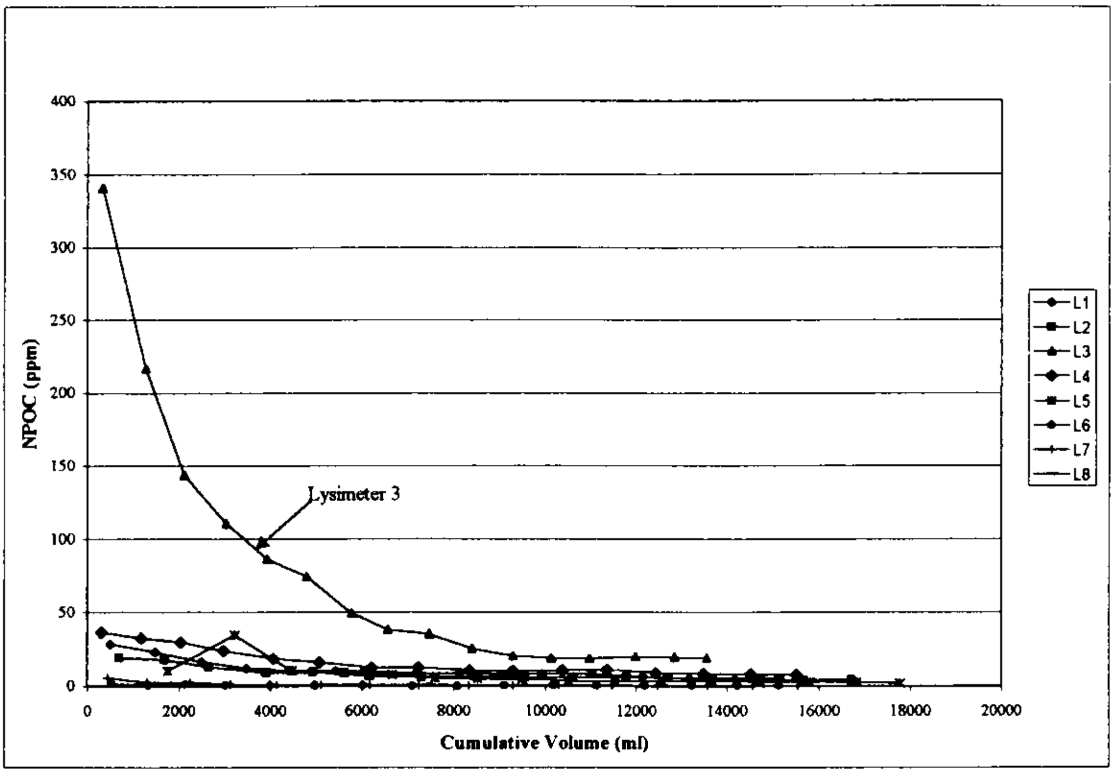


Figure 4-3. Nonpurgible Organic Carbon

Conductivity and TDS are related. The more total dissolved solids, the more ions available to produce conductance. Table 4-7 shows some relationship between them, and this was further investigated. The ions contribute to the TDS and conductivity and Table 4-8 contains all of the ions analyzed for as well as their ranges and averages. As mentioned earlier, a relationship exists between conductivity, ions, and TDS. Table 4-9 is a "solids balance" for the total amount of ions leached and the total TDS leached for each lysimeter. The sums match up well, with all ion sums slightly lower. Differences may be explained by organic matter (Lys 3) and other non-detected ions. Figure 4-4 presents the leaching curve for conductivity. This same trend was followed by TDS and ions.

Table 4-8. Ions found in Lysimeter Leachate (mg/L).

	L1	L2	L3	L4	L5	L6	L7	L8
No. Collected	20	20	20	20	20	20	20	20
Avg. Sulfate	32.3	26.9	49.8	67.0	8.2	26.6	25.4	4.0
Max	129.2	115.7	275.4	195.2	14.5	107.2	108.1	10.6
Min	15.9	5.9	9.3	31.1	5.4	3.9	8.8	2.9
Avg. Nitrate	11.9	8.7	8.5	21.4	3.9	9.6	8.3	6.8
Max	109.6	84.9	107.3	285.5	30.1	111.6	90.8	43.1
Min	3.6	2.5	2.0	2.0	2.1	2.2	2.7	3.0
Avg. Chloride	24.3	21.1	6.5	35.7	4.4	6.2	3.0	2.5
Max	129.8	113.7	28.4	159.9	10.6	26.7	5.0	3.2
Min	9.0	4.9	2.8	7.8	2.9	2.7	2.5	0.0
Avg. Fluoride	1.2	1.1	1.0	0.9	1.0	0.7	0.4	0.0
Max	1.6	1.4	1.3	1.0	1.1	1.0	0.8	0.0
Min	1.0	0.9	0.8	0.7	0.8	0.5	0.0	0.0
Avg. Calcium	76.4	73.7	84.5	71.8	43.5	14.0	10.8	2.5
Max	104.8	96.1	122.0	97.1	55.1	44.7	48.3	11.3
Min	58.2	48.6	53.4	50.0	34.9	4.2	0.0	0.0
Avg. Potassium	4.6	3.6	4.9	9.1	1.1	1.1	0.3	0.0
Max	14.9	11.3	12.8	20.3	2.7	3.1	1.2	0.1
Min	1.7	1.7	2.6	3.7	0.5	0.6	0.0	0.0
Avg. Magnesium	39.1	34.0	14.3	46.9	3.1	3.8	1.0	0.0
Max	87.2	77.8	48.3	92.5	6.8	21.9	8.5	0.2
Min	14.7	16.0	4.5	22.7	0.0	0.4	0.0	0.0
Avg. Sodium	12.6	10.0	5.7	35.8	1.8	4.7	0.3	0.2
Max	105.1	75.1	31.0	172.4	7.9	21.2	1.7	0.5
Min	1.9	2.1	0.2	3.1	0.1	0.7	0.0	0.0

Table 4-9. Solids Balance for Ions and TDS (g).

	LYS 1	**LYS 2**	**LYS 3**	**LYS 4**	**LYS 5**	**LYS 6**	**LYS 7**	**LYS 8**
Sulfate	0.64	0.57	0.81	1.33	0.18	0.50	0.49	0.08
Nitrate	0.23	0.18	0.14	0.39	0.09	0.16	0.15	0.14
Chloride	0.48	0.44	0.10	0.68	0.10	0.12	0.06	0.05
Fluoride	0.02	0.02	0.02	0.02	0.02	0.02	0.01	0.00
Carbonate	3.73	3.74	2.63	3.46	1.52	0.01	0	0
Calcium	1.53	1.56	1.42	1.47	0.93	0.27	0.21	0.05
Potassium	0.09	0.08	0.08	0.18	0.02	0.02	0.01	0.00
Magnesium	0.76	0.73	0.25	0.95	0.07	0.07	0.02	0.00
Sodium	0.25	0.21	0.11	0.69	0.04	0.09	0.01	0.00
Ion Sum	**7.73**	**7.52**	**5.55**	**9.16**	**2.97**	**1.24**	**0.95**	**0.33**
TDS	**9.45**	**8.77**	**8.26**	**10.38**	**5.65**	**1.71**	**1.16**	**0.99**

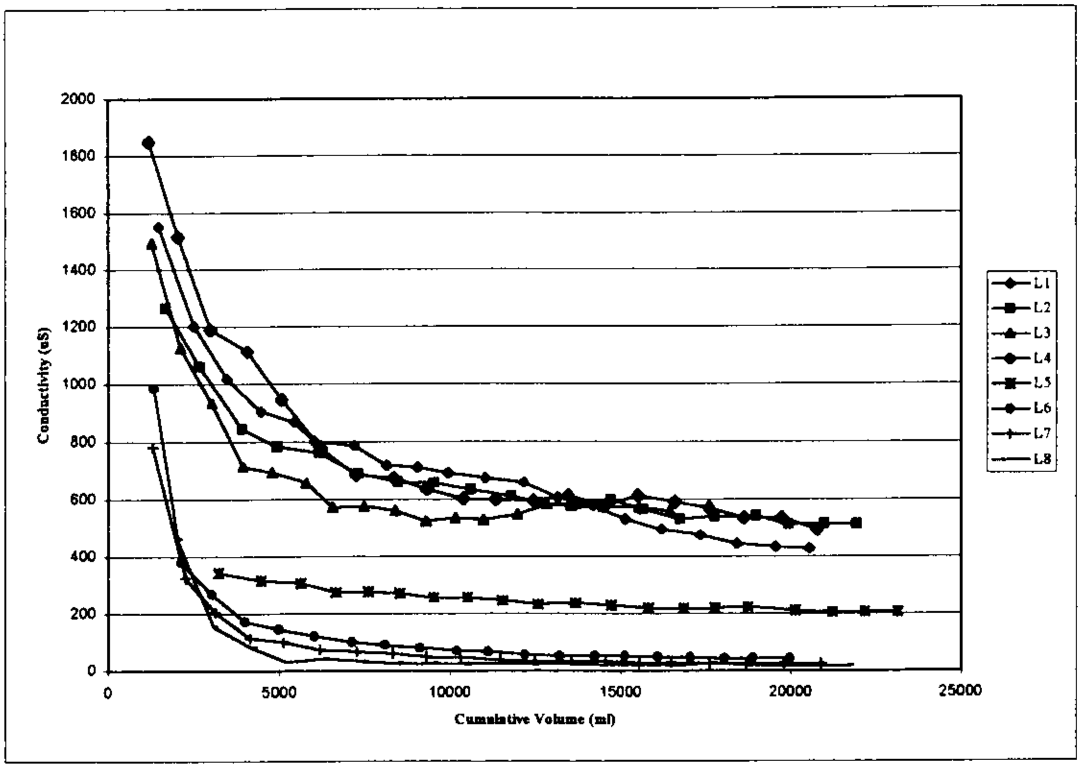


Figure 4-4. Conductivity

Heavy Metals

Many of the general parameters and ions followed a similar leaching curve. Leachate samples were analyzed for typical metals found in waste ABM (Chapter 2 and 3) to see if like curves were formed by the leaching of the metals from this waste stream. Metal samples were taken 10 times (except lysimeter 3,8 times) during the 6 week study. Table 4-10 presents the number of detected samples out of 10 (8 for L3) for each metal.

Table 4-10. Heavy Metals found in Lysimeter Leachate (mg/L).

	L1	**L2**	**L3**	**L4**	**L5**	**L6**	**L7**	**L8**
No. Detected	0	0	2	0	10	0	0	0
Max Cadmium	N/A	N/A	10.81	N/A	3.94	N/A	N/A	N/A
Min Cadmium	N/A	N/A	<.001	N/A	0.48	N/A	N/A	N/A
No. Detected	1	1	2	3	2	2	2	1
Max Chromium	.034	.027	.082	.107	.005	.035	.042	.013
Min Chromium	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
No. Detected	10	10	0	10	0	0	0	0
Max Copper	0.74	1.3	N/A	1.9	N/A	N/A	N/A	N/A
Min Copper	0.22	0.28	N/A	0.44	N/A	N/A	N/A	N/A
No. Detected	6	6	8	4	7	8	6	6
Max Iron	0.59	0.69	20.61	1.27	0.95	1.35	1.23	0.27
Min Iron	<0.01	<0.01	1.34	<0.01	<0.01	<0.01	<0.01	<0.01
No. Detected	3	1	1	2	9	1	1	0
Max Lead	.011	.005	.028	.023	.043	.002	.001	N/A
Min Lead	0.001	0.001	0.001	0.001	0.000	0.001	0.001	N/A
No. Detected	0	0	0	1	1	1	0	0
Max Nickel	N/A	N/A	N/A	0.16	0.12	0.18	N/A	N/A
Min Nickel	N/A	N/A	N/A	0.01	0.01	0.01	N/A	N/A
No. Detected	10	10	3	10	10	0	0	0
Max Zinc	7.29	7.77	1.59	6.82	86.79	N/A	N/A	N/A
Min Zinc	2.09	2.62	0.01	1.93	9.35	N/A	N/A	N/A

The metals that expressed leaching curves in various lysimeters were zinc, copper, lead, and iron. Figures 4-5 through 4-8 show the leaching curves for these metals from their respective lysimeters.

Consist Lead with pg. 20.

L1, L2, L4 all ship AB[illegible]

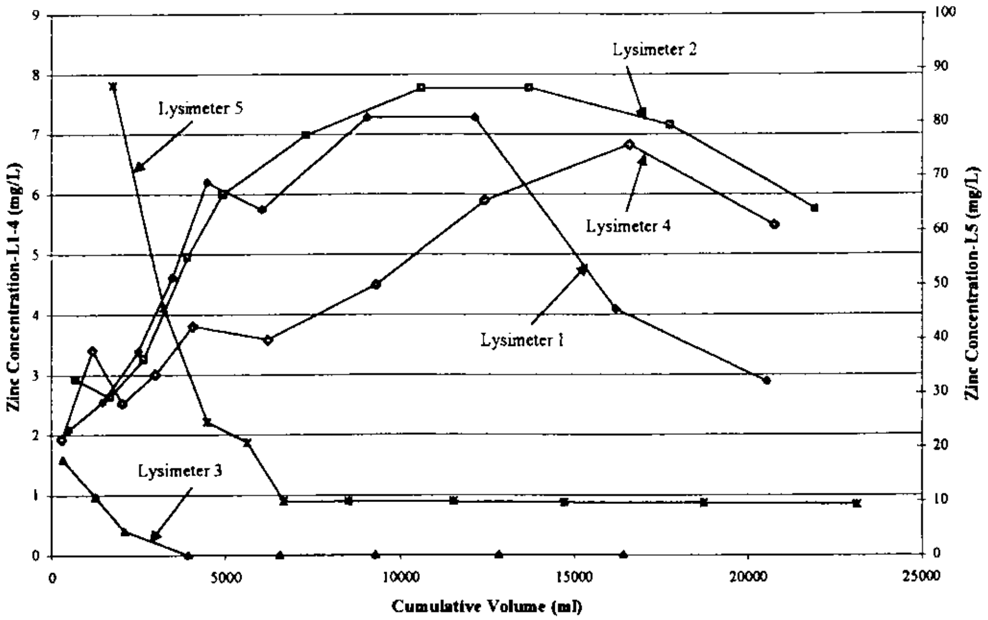


Figure 4-5. Zinc Leaching from Lysimeters.

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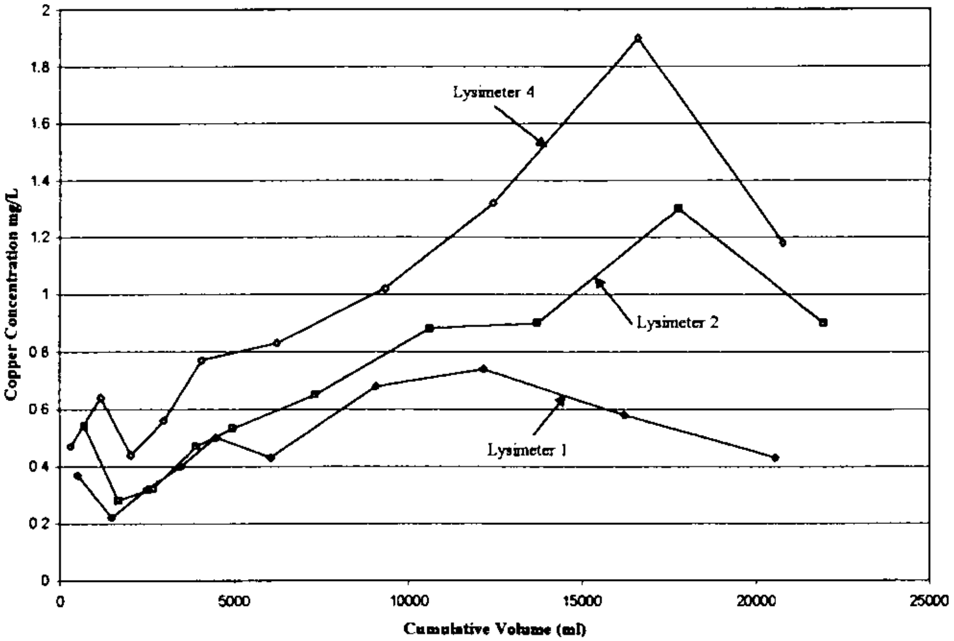

Figure 4-6. Copper Leaching from Lysimeters.

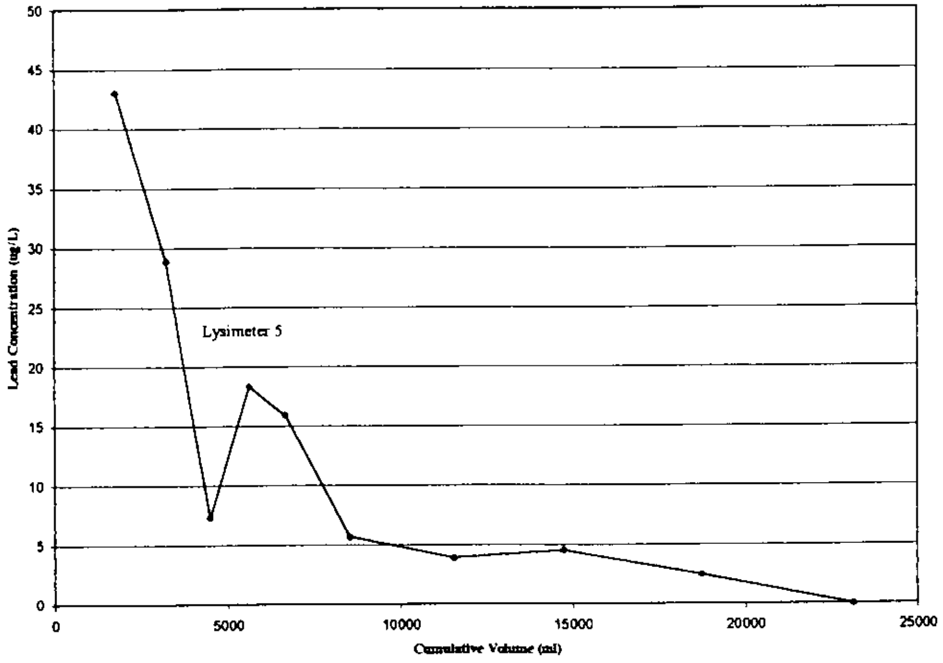

Figure 4-7. Lead Leaching from Lysimeter 5.

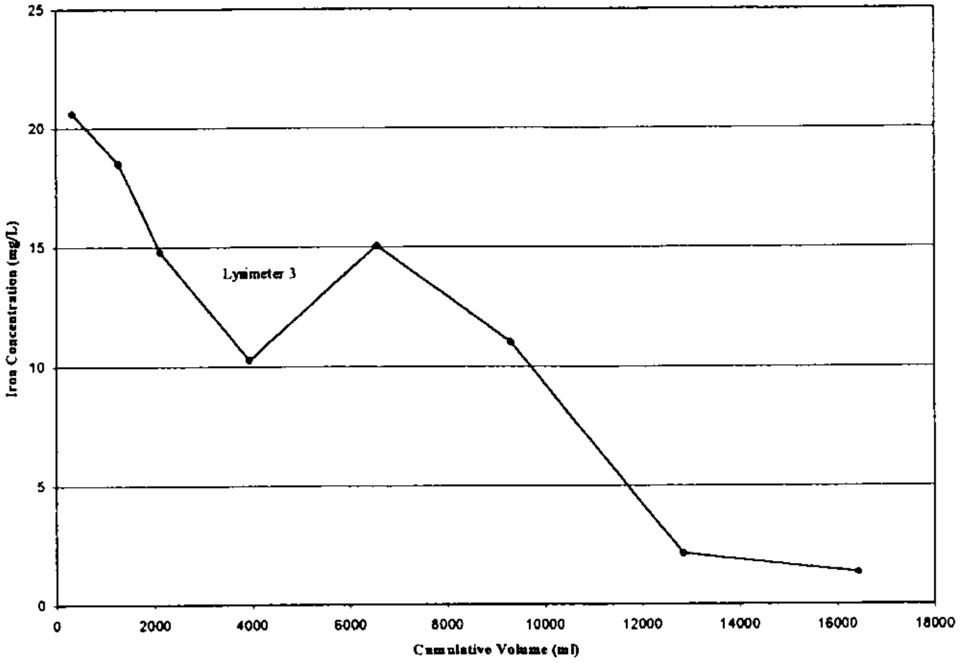

Figure 4-8. Iron Leaching from Lysimeter 3.

Discussion

Leaching Curves

All of the measured parameters from the lysimeters demonstrated leaching characteristics. These characteristics plotted versus cumulative volume presented a leaching curve. Many of the general water quality parameters and all of the ions had a similar curve, starting at a maximum value then decreasing to a steady state. One reason for this phenomenon is that concentrations in the waste stream are high to begin with and then as constituents get washed away, the concentrations fall to a steady state. Normally, leaching mechanisms are much more complex than that and are affected by physical (e.g. particle size, porosity) and chemical parameters (e.g. pH and oxidation reduction potential). A brief discussion of some of these parameters follows.

The relationship of pH on the leaching of wastes has been examined to some extent and the leaching behavior of contaminants as a function of pH is very systematic (van der Sloot, 1991). There is typically a pH range where maximum and minimum leaching will occur for separate metals.

Physical parameters can also affect the leachability of contaminants from waste. A smaller particle size allows for more surface area for a contaminant to leach from. A paint chip in waste ABM would leach differently than a particle of the media itself. As presented earlier, in coal slag media, zinc, copper, and lead for the most part came from the use of the media (paint or coating) and other metals are inherent to the media (As, Ni, Cr).

Generally, highly soluble constituents will wash out of a system quickly and less soluble constituents will leach at a consistent rate leading to a continuous increase (van der Sloot, 1991) and then decrease again as the contaminant is washed away. This leaching characteristic may explain why some of the leaching graphs increase and then decrease while others simply decrease. The solubility of the same metal in a different lysimeter would be affected by the individual conditions of that lysimeter.

Another leaching mechanism that may produce different leaching curves is channeling. Fluid may be traveling through certain paths and then find its way into other areas causing the "bump" produced in the leaching curves of lead and iron. A chemical parameter may also have caused those two metals to react that way.

Leaching Comparisons

The concentrations of metals leached from the TCLP correlated with the total metal concentrations for zinc, copper and lead. The correlation coefficient for this relationship for zinc, copper, and lead are 0.89, 0.93, and 0.82 respectively (Figures 4-9 through 4-11). Samples which leached, but were below the total metal detection limit were assumed half of the limit (for copper and lead only).

good

probably not. TCLP too aggressive?

Were the SPLP tests not a good correlation with total metals?

Does This suggest a mechanism for managing The ABM? Test waste pile for total Zinc, copper & lead use correlation to decide what amt is too high or use the other approach. Start with gw standard & back calculate max allowable concentration for these metals. recommended max.

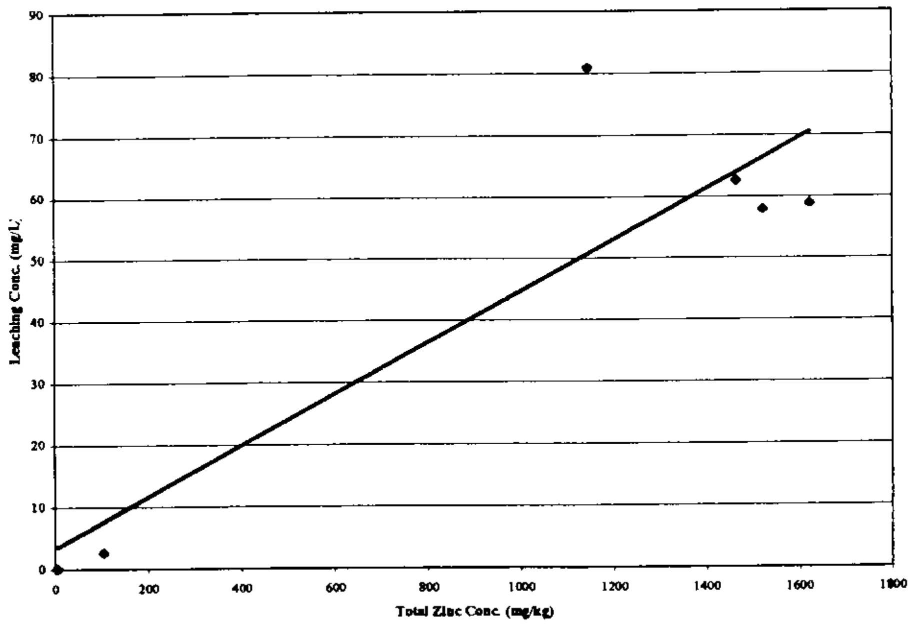

Figure 4-9. Zinc TCLP and Total Metal Correlation.

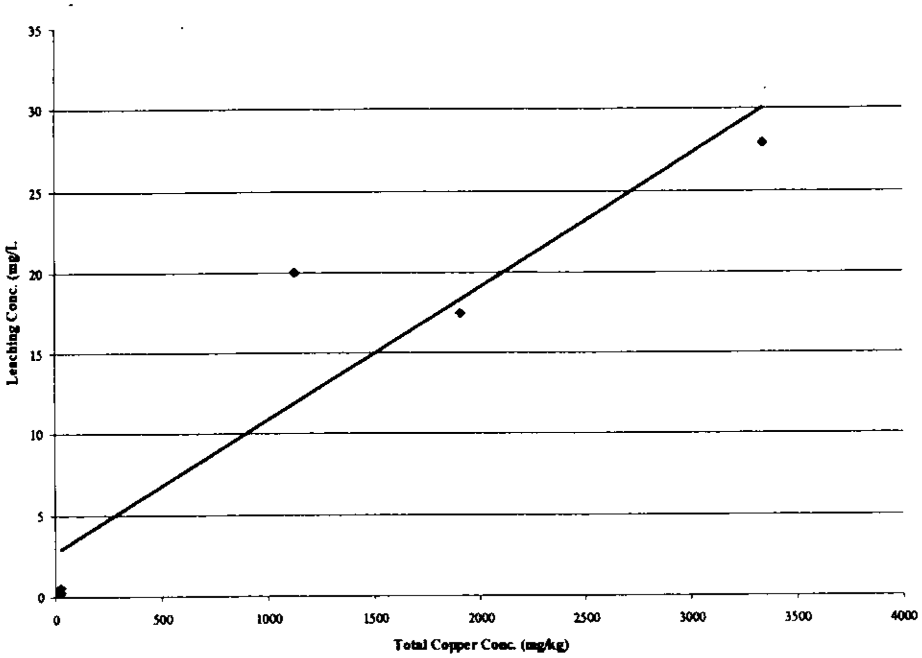

Figure 4-10. Copper TCLP and Total Metal Correlation.

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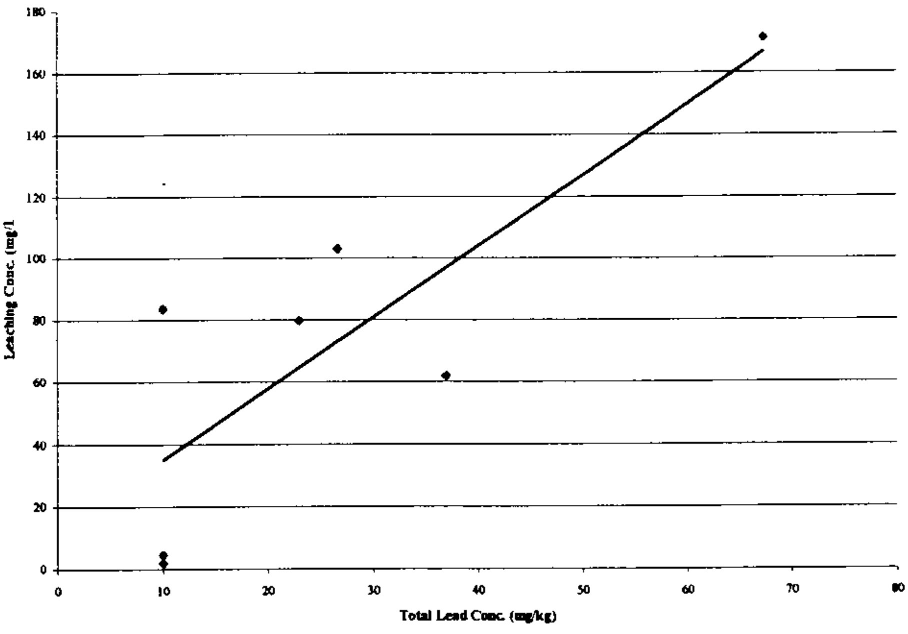

Figure 4-11. Lead TCLP and Total Metal Correlation.

A percentage of the total metals leached during the TCLP, SPLP, and lysimeter tests. Tables 4-6 through 4-8 show the percent leaching for all tests. The leaching mechanisms of the TCLP and SPLP test also differ. However, there was some correlation for all samples leaching above detection limit for SPLP and TCLP. Figure 4-12 illustrates this correlation with a 0.80 coefficient.

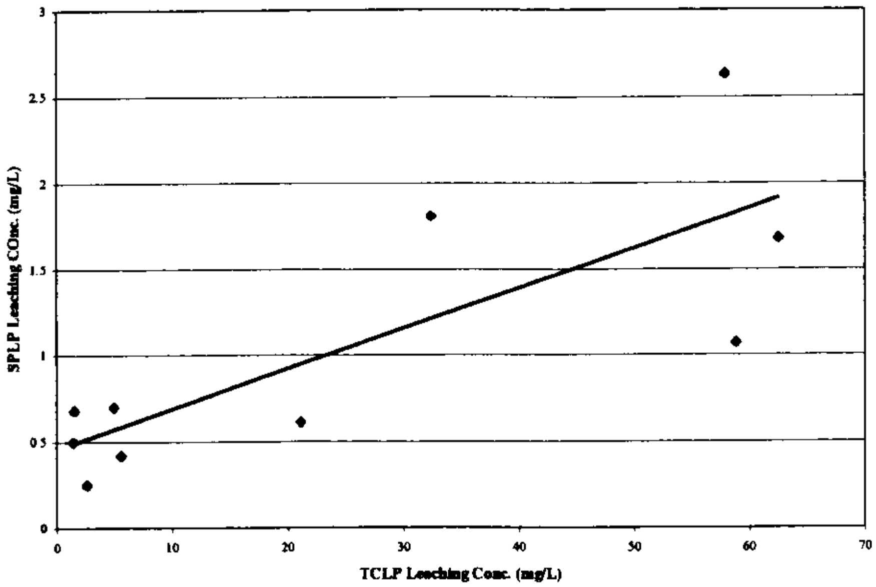

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Figure 4-12. TCLP and SPLP Correlation

Table 4-6. Percent Leaching for Copper.

Copper	L1	L2	L4
TCLP	18.3%	35.6%	16.7%
SPLP	<0.52%	<0.89%	<0.30%
Lysimeter	0.2%	0.5%	0.2%

Table 4-7. Percent Leaching for Lead.

Lead	L1	L2	L3	L4	L5
TCLP	7.7%	6.9%	3.3%	5.1%	8.4%
SPLP	<0.75%	<0.87%	<0.5%	<0.3%	<1.0%
Lysimeter	0.04%	0.02%	0.04%	0.03%	0.49%

Table 4-8. Percent Leaching for Zinc.

Zinc	L1	L2	L3	L4	L5
TCLP	85.5%	76.0%	50.5%	72.5%	56.5%
SPLP	2.3%	3.5%	4.8%	1.3%	3.2%
Lysimeter	2.5%	2.9%	1.7%	2.0%	15.4%

Implications for Characterization

The leaching percentages of the TCLP test are higher than the SPLP or lysimeter leaching. The TCLP test is more aggressive in simulating the anaerobic leaching conditions at the bottom of a landfill with acetic acid. The TCLP would not be a good representation of the leaching of a waste in non-landfilled or open environmental conditions. The SPLP test is much better suited for predicting the leachate produced in the environment and is recommended by some regulators (WDNR). Tables 4-6 through 4-8 show that the lysimeter column was very similar to the SPLP test for percentage of total metal leached.

The batch leaching tests predict the concentration of metals in leachate produced, while taking into account the dilution of the leachate in the environment, by keeping the liquid to solid ratio at 20:1. The lysimeters, although they may simulate field and environmental conditions more accurately, by allowing the liquid to percolate though the waste, do not account for dilution in the environment. This can be seen by the high maximums on the lysimeter metal leaching curves. A dilution factor may need to be incorporated into the lysimeter leaching numbers to properly asses the impact of this waste stream on the natural environment.

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When a dilution factor of 20 is applied to the lysimeter leaching data one secondary drinking water standard is exceeded by an average concentration. Lysimeter 3 exceeds the secondary limit of 0.3 mg/L for iron. All other lysimeters are under primary and secondary limits. This characterization of these wastes is somewhat different than the characterization made in chapters 2 and 3. Some ship maintenance facility media exceeded secondary drinking waster levels for zinc, iron, and copper. The sandblasting contractor sites exceeded for iron also. Even though exact environmental conditions are not simulated by the lysimeter leaching tests, these tests can give an indication of how this waste will behave when it is exposed to rain that filters through the waste to produce leachate.

Conclusions

The management of waste abrasive blasting media is a relatively new problem. Many times in the past, the waste was allowed to accumulate on site, with out any disposal. This accumulation of waste is normally a regulatory violation, as a landfill cannot be operated with out a permit and other provisions. A recommendation by regulators for the disposal of ABM waste has been in a lined landfill, because the characteristics leaching from the waste were unknown. This study researched the different leaching characteristics and total metal content of the waste stream. These characteristics may be used by generators and regulators to better understand the mechanism of leaching for this and other ABM-like waste streams.

Similar metals showed up in the leaching columns that were considered an issue from Chapters 2 and 3. When a dilution factor is applied to the lysimeter data, one metal still exceeds the secondary drinking water standard for iron at the top of the leaching curve.

CHAPTER 5
CONCLUSION

With regulatory trends moving towards risk-based standards and guidelines, the management of small specific waste streams, such as abrasive blasting waste, will become more complex. Through previous research a decision-making process was developed for the assessment and management of waste ABM (Carlson and Townsend, 1998).

This Research

This research utilized the decision making process for the assessment of two different waste streams of ABM (ship maintenance facility waste and sandblasting contractor waste). A brief outline of the conclusions from the decision making process follows:

1. Both waste streams from the sites sampled were non-hazardous for the toxicity characteristic.
2. Comparing total metal concentrations to direct exposure standards showed that in the ship maintenance waste ABM, arsenic was over the federal SSL 65% of the time, however only 2 samples exceeded the Industrial Florida soil cleanup goal (FSCG). The geometric average for the arsenic data was below the industrial FSCG. Another ship maintenance sample exceeded the federal limit for lead, however the average remained below the limits. None of the sandblasting contractor waste exceeded any risk-based direct exposure limits.

3. Comparing leachable metal concentrations to drinking water standards showed that ship maintenance facility waste ABM could occasionally exceed the primary standard for lead (1 sample) and may exceed the secondary standards for copper, iron, and zinc. Both geometric means for copper and iron were below the secondary drinking water standards, however the mean for zinc exceeded the limit. The sandblasting contractor waste had one sample exceeding the primary standard for cadmium, while the geometric mean was below the limit. The secondary limit for iron was exceeded by the geometric mean of the sandblasting contractor samples.
4. Options for management of these waste streams include disposal in a lined landfill and recycling in manner which does not produce leachate that enters the environment. Storage on-site would be allowed as long as production of leachate was kept to a minimum.

Since Chapter 2 and 3 indicate that these waste streams could potentially pose a risk to human health and the environment when compared to secondary drinking water standards, this leaching behavior was investigated further in Chapter 4. Chapter 4 compared batch tests similar to those used to regularly characterize waste (TCLP and SPLP) to a leaching column study. A leaching column study can be more representative of how waste may actually leach in the environment because the leaching fluid flows through the waste in a similar manner to rain. Chemical conditions inside the lysimeter also affect the leachability of a waste and may over or under-estimate the actual leaching that could occur in the environment (van der Sloot, 1991).

Future Work

This research provides insight into the characteristic of the two waste streams studied, but also raises some questions regarding the characteristics and management of abrasive blasting media. The leaching column study provided some indication on how this waste behaves in the environment, but actual field-testing would greatly increase the confidence of these results. The comparison of leaching methods in Chapter 4 can be beneficial for future testing purposes.

The theoretical leaching approach could be explored further. With the extensive leaching studies completed for this research and many general parameters recorded, a leaching model could be developed for the waste ABM from the lysimeter leaching situation. This model could theoretically predict a total metal concentration (similar to the federal SSLs that did not seem appropriate for ABM waste) that would be likely to exceed drinking water standards. These would be highly useful numbers to generators of this waste because total metal analyses are less expensive that leaching analyses.

A final option that could be explored would be to examine the leachability of this waste as treatment. When the waste has conditions similar to those in this study, the contaminants leach off relatively quickly and if the leachate is collected and treated, this may be a less expensive way to handle this waste stream.

APPENDIX A

QA/QC DATA

Table A-1. QA/QC Data

	TOTALS			**LEACH**				
	Blk.Spike	MS1	MS2	Blk. Spike	MS1	MS2	MS3	MS4
Zinc	92%	112%	111%	101%	79%	65%	101%	72%
Copper	94%	112%	112%	136%	105%	108%	141%	147%
Lead	90%	82%	82%	110%	119%	132%	115%	110%
Chromim	105%	74%	66%	103%	105%	104%	107%	108%
Cadmium	92%	89%	92%	80%	85%	75%	80%	85%
Nickel	100%	94%	86%	85%	90%	88%	84%	79%
Iron	106%	60%	79%	121%	112%	133%	88%	115%
Arsenic	128%	60%	54%	98%	-	-	-	-
Selenium	75%	84%	78%	85%	-	-	-	-
Barium	-	-	-	90%	80%	120%	-	-
Silver	-	-	-	-	41%	71%	-	-
Mercury	-	87%	109%	-	83%	66%	-	-

NOTE: MS=MATRIX SPIKE

APPENDIX B

LYSIMETER DATA

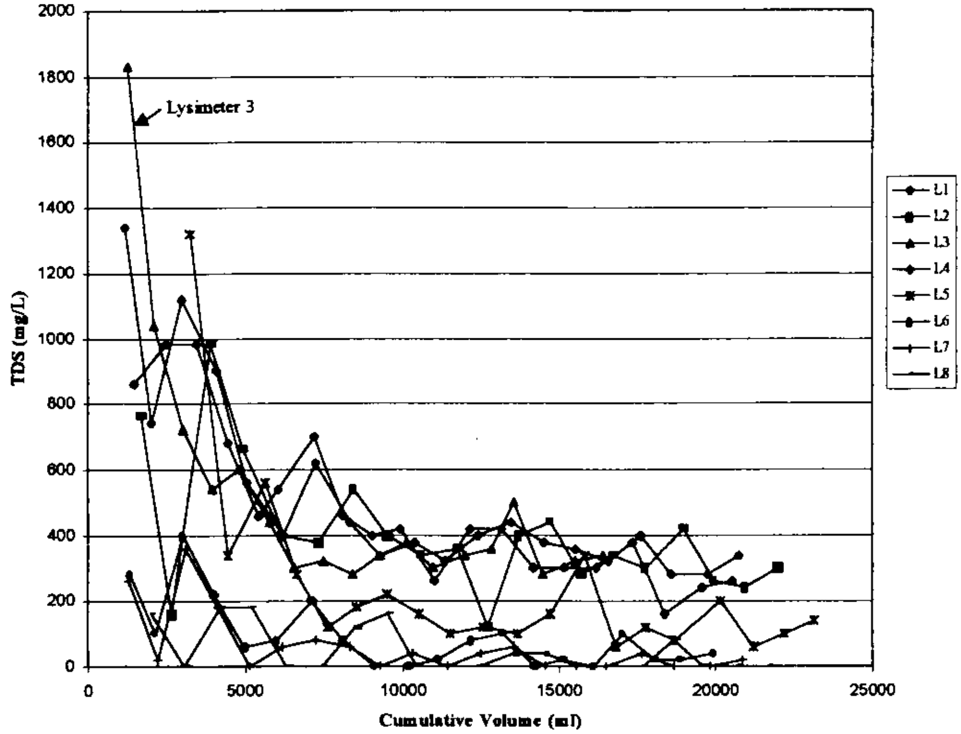

Figure B-1. TDS Leaching Curves.

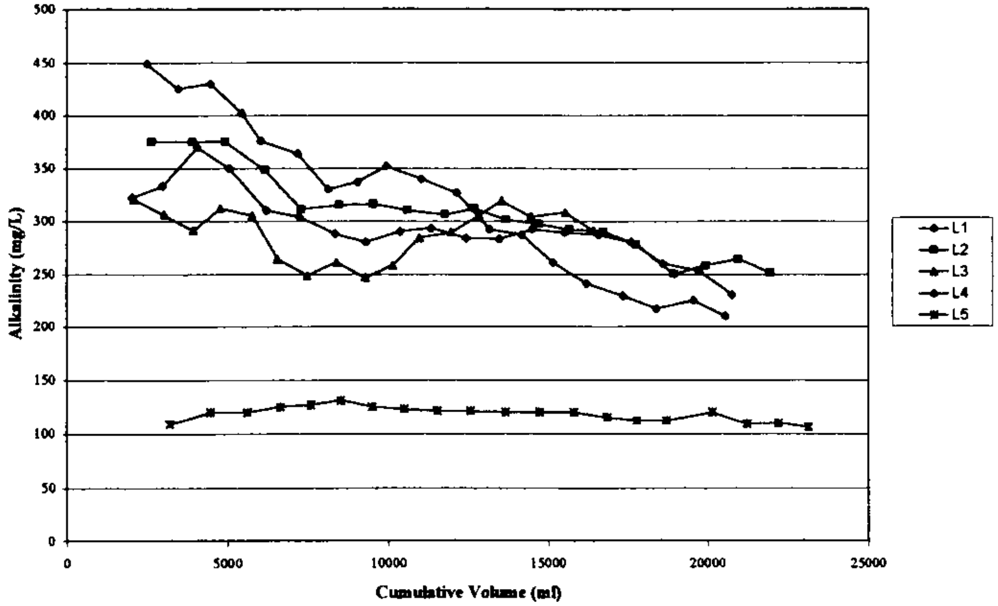

Figure B-2. Alkalinity Leaching Curves.

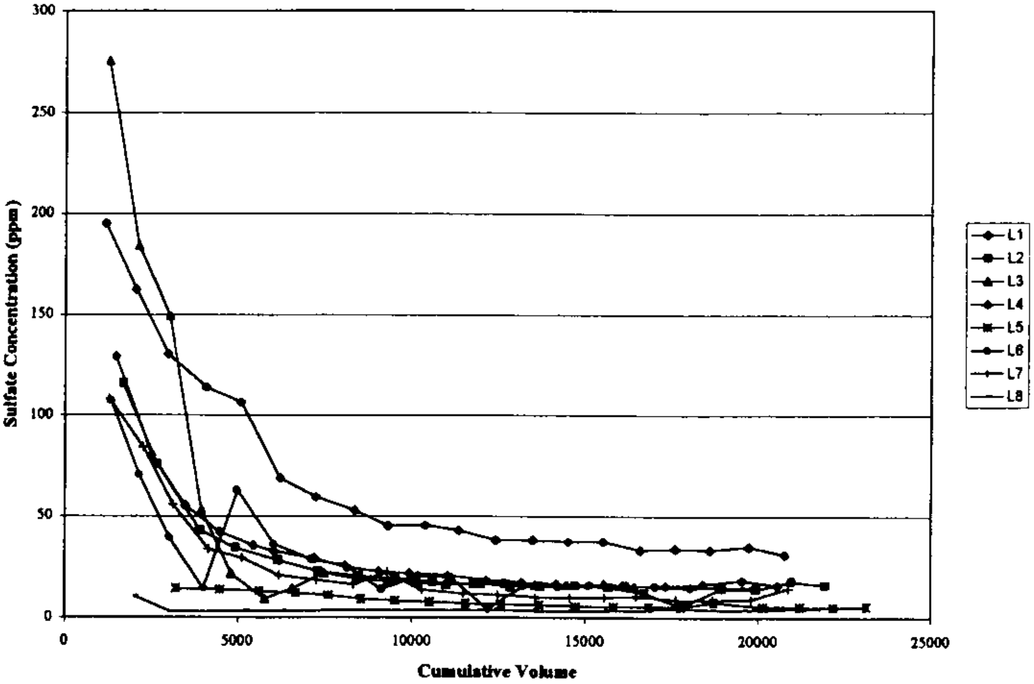

Figure B-3. Sulfate Leaching Curves

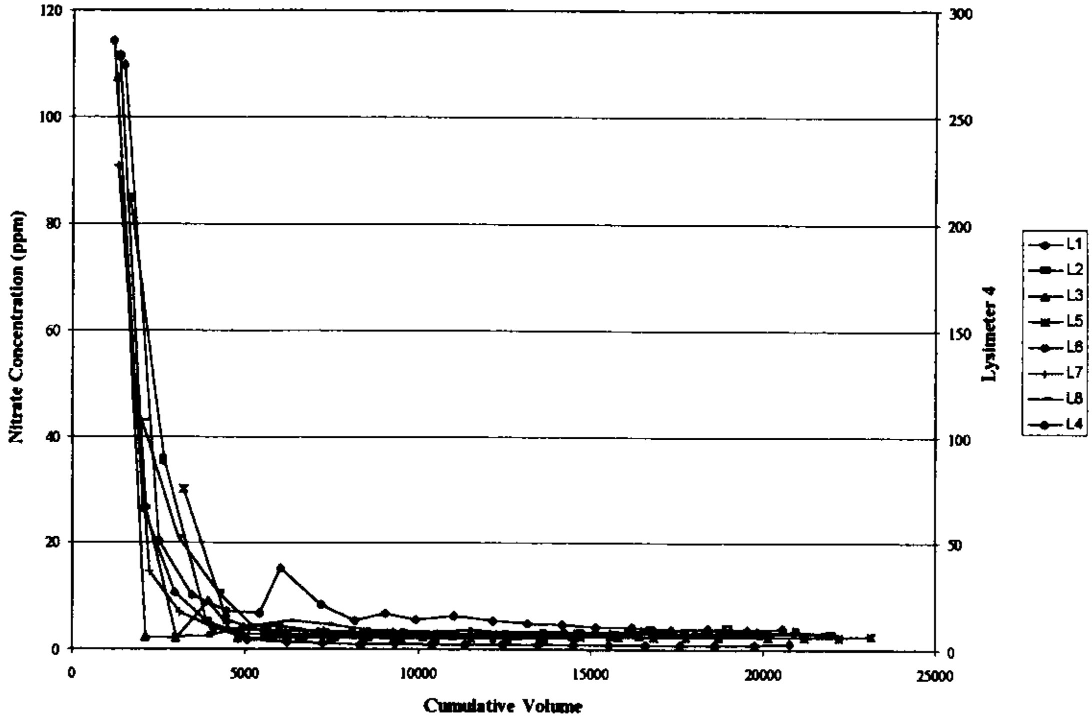

Figure B-4. Nitrate Leaching Curves

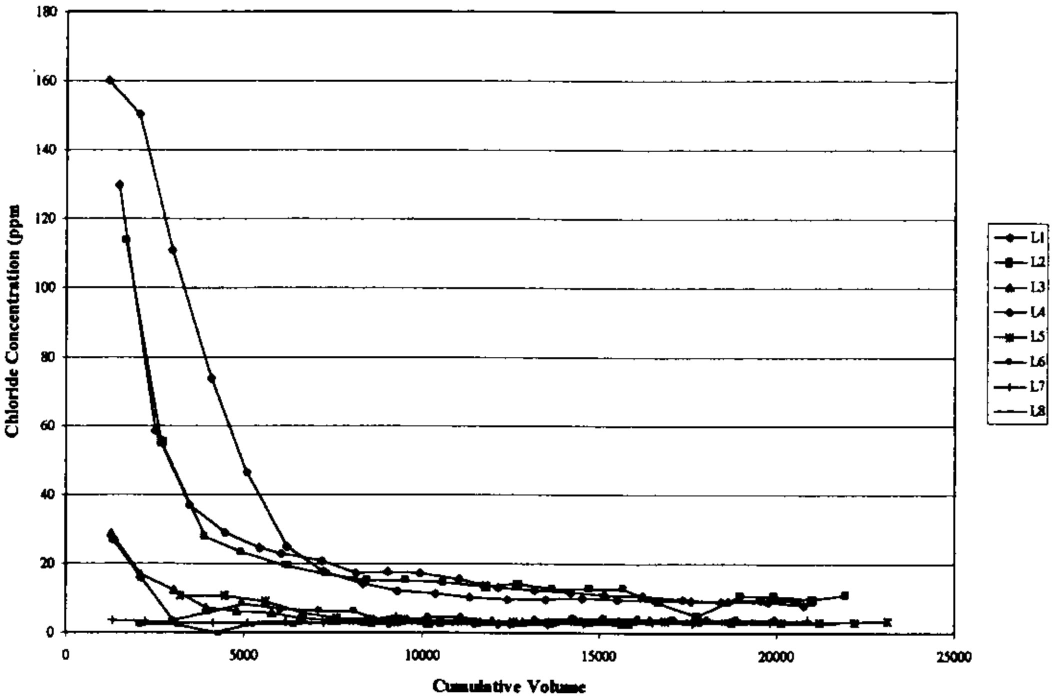

Figure B-5. Chloride Leaching Curves.

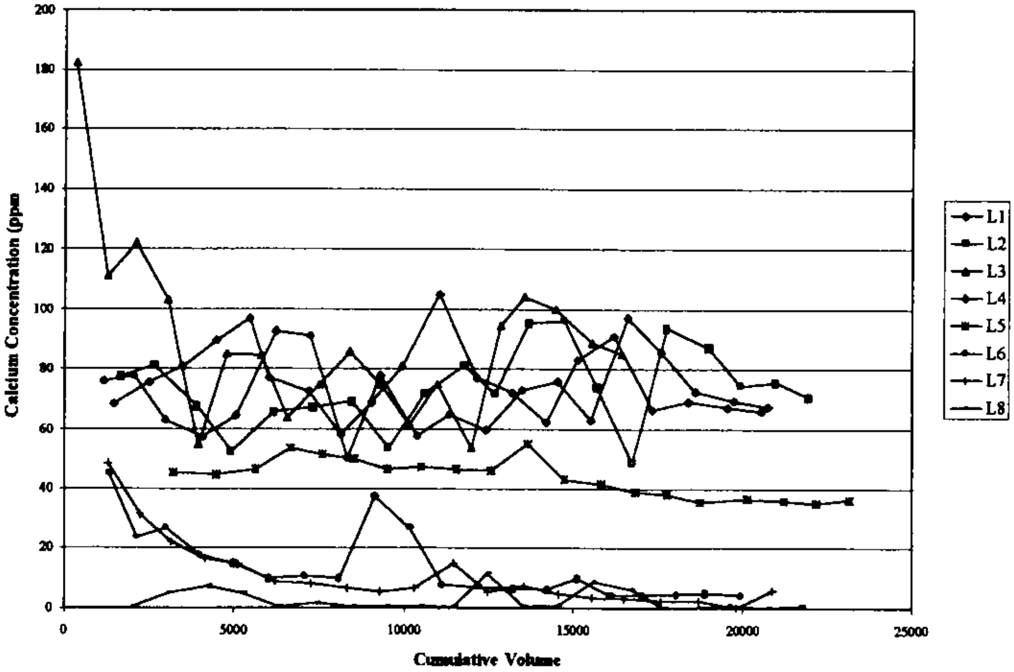

Figure B-6. Calcium Leaching Curves.

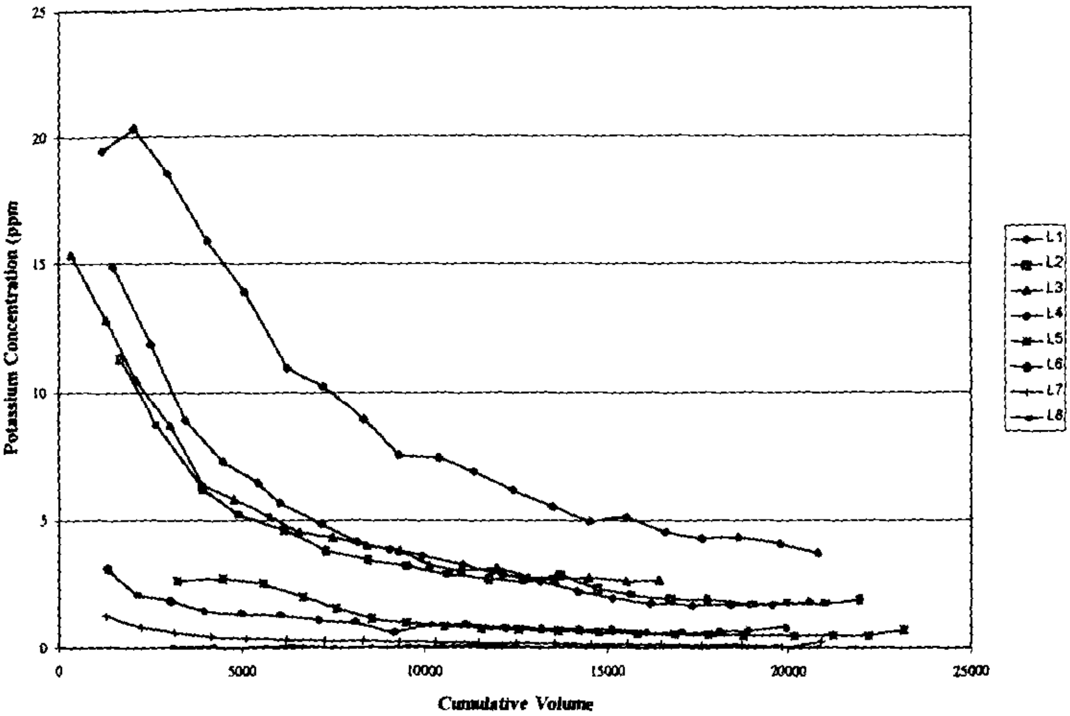

Figure B-7. Potassium Leaching Curves.

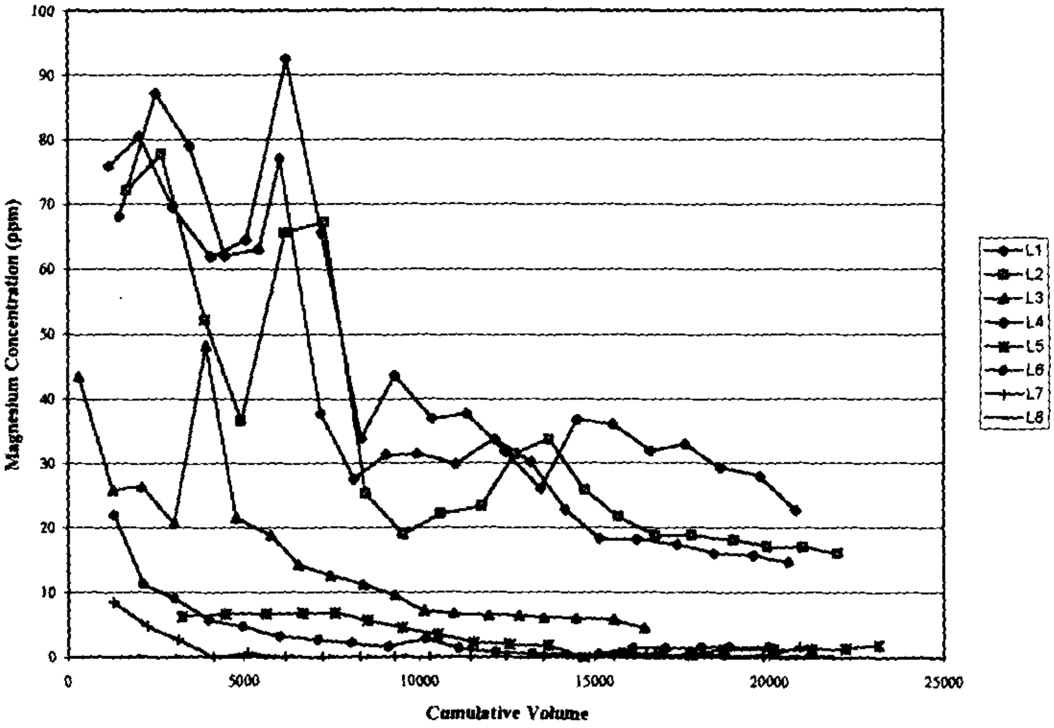

Figure B-8. Magnesium Leaching Curves.

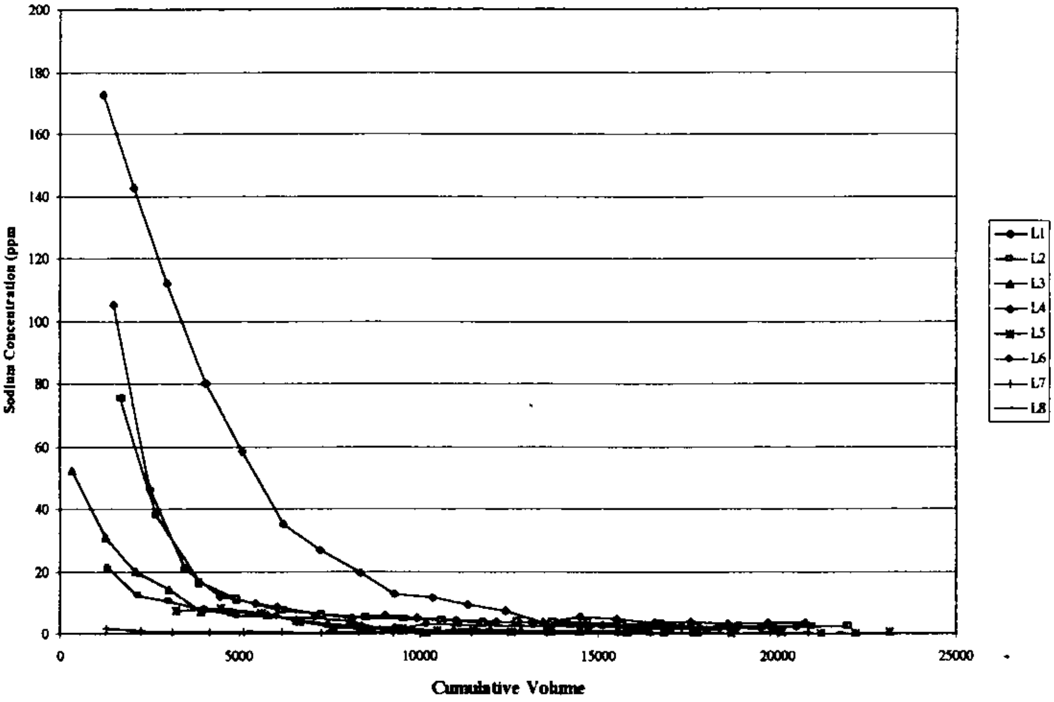

Figure B-9. Sodium Leaching Curves.

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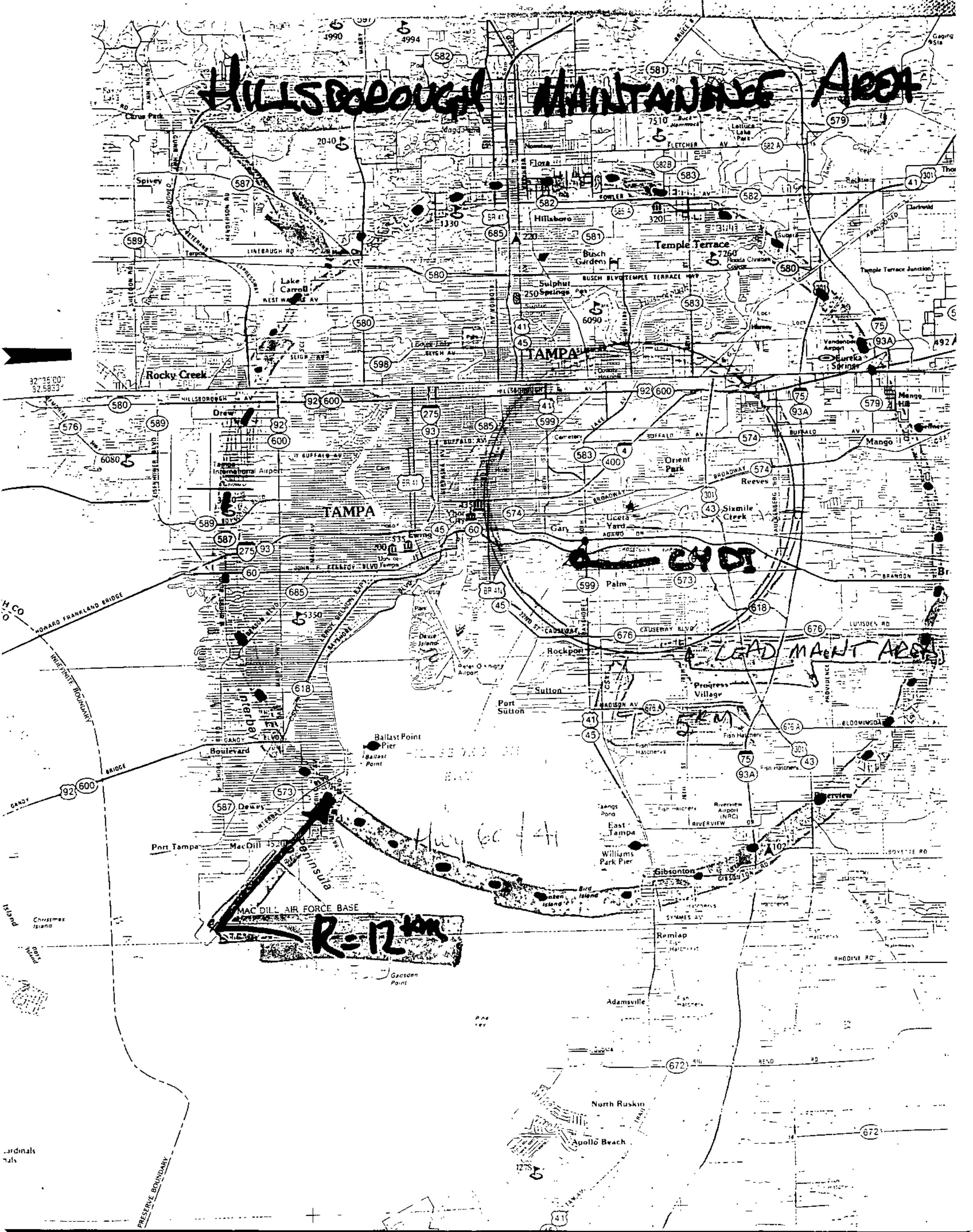
BIOGRAPHICAL SKETCH

Jenna Romness Jambeck Carlson was born on April 16, 1974 in Minneapolis, Minnesota. Her parents divorced when she was one year old, with her father and step mother moving to Florida soon after. Jenna grew up and went to school in the small town of Pine City, Minnesota. However, she visited Florida an average of four times a year and attended eighth grade at Cypress Lake Middle School in Fort Myers. Jenna graduated in May 1992 from Pine City High School as salutatorian and Vice President of her class, with a Tozer Scholarship. She also received a scholarship from the Pine City Masons for a paragraph she wrote about her aspirations to pursue a degree in Environmental Engineering.

She attended the University of Florida (where her brother was) and received her Bachelor of Sciences in Environmental Engineering with honors in 1996. Jenna began her graduate career with a grant in January of 1997 specializing in solid and hazardous waste management, in the Department of Environmental Engineering. On July 12, 1997 she married her long time beaux and best friend, Brian Carlson. Upon completing her Master's Degree, Jenna and Brian will be relocating to Minneapolis, Minnesota where Jenna is employed by Woodward-Clyde/URS Greiner.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Lake Carroll
Rocky Creek
Drew
Tampa International Airport
Hillsboro
Busch Gardens
Sulphur Springs
Temple Terrace
Temple Terrace Junction
Flora
Vandenberg Airport
Eureka Springs
Mango
Orient Park
Reeves
Sixmile Creek
Uceta Yard
Gary
Ybor City
Palm
Rockport
Progress Village
Port Sutton
Ballast Point Pier
Boulevard
Interbay
Dewey
Port Tampa
MacDill
Peninsula
MAC DILL AIR FORCE BASE
Gadsden Point
East Tampa
Williams Park Pier
Gibsonton
Riverview
Riverview Airport (NRC)
Bird Island
Remlap
Adamsville
North Ruskin
Apollo Beach
Christmas Island
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GANDY BRIDGE
HILLSBOROUGH AV
BUFFALO AV
BROADWAY
CAUSEWAY BLVD
FLETCHER AV
FOWLER AV
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