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Daytona Beach, FL 32115

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Vice Pres., Industrial Development
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Conrad Yelvington Distributors, Inc.
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Daytona Beach, FL 32115

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DEPARTMENT OF ENVIRONMENTAL PROTECTION
DIVISION OF AIR RESOURCES MANAGEMENT
BUREAU OF AIR REGULATION - TITLE V
2600 BLAIR STONE ROAD
TALLAHASSEE, FLORIDA 32399-2400
MS 5505

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Bill \ File

Department of
Environmental Protection

Jeb Bush
Governor

Twin Towers Office Building
2600 Blair Stone Road
Tallahassee, Florida 32399-2400

David B. Struhs
Secretary

October 16, 2000

CERTIFIED MAIL RETURN RECEIPT REQUESTED

Mr. William C. Thomas, III
Vice President of Industrial Development & Operations
Conrad Yelvington Distributors, Inc.
Post Office Box 1686
Daytona Beach, Florida 32115

Re: Completeness review for an Amended Application for an Air Construction Permit
Powerscreen Sand and Gravel Classifier: Permit No.: 7770473-001-AC

Dear Mr. Thomas:

The Department has reviewed the amended application for use of the Powerscreen unit for processing spent abrasive blasting media, (spent ABM). Based on a review of this amended application, we consider it to be incomplete. Please submit the following information, including all calculations, assumptions and reference material, and any changed application pages that are appropriate to the Department, and we will begin reviewing and processing the latest request when we receive the requested information.

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.

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.

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.

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.

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.

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.

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.

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.

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.

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.

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.

Sincerely,

W. Leffler

William Leffler, P.E.
Permitting Engineer

Enclosures: Carlson and Townsend papers

Cc:
Stephanie S. Brooks, P.E. Brooks and Associates, Inc.
Clair Fancy, BAR w/o enclosure
Bruce Mitchell, BAR w/o enclosure
Jerry Campbell, Hillsborough County Environmental Protection Commission
Richard B. Tedder, Division of Waste Management w/o enclosure

Leffler, William

From: Butera, Robert
Sent: Friday, January 26, 2001 7:12 PM
To: Leffler, William
Cc: Tedder, Richard
Subject: Conrad Yelvington Distributors, Inc. - Air Construction Permit 7770473-001-AC

October 20th I received an incompleteness letter you sent from Richard Tedder requesting additional information relating to the referenced permit for a Power screen unit (mobile) to process spent abrasive blasting media, spent ABM. Please let me know the status of the permit application as (Richard- you will appreciate this) this facility is leasing property from (Hardaway Corporation), a GWCU 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.....so any status on the air permit would be helpful. It appears they were using the power screen at the site prior to you issuing them a permit as well.

Department of
Environmental Protection

Jeb Bush
Governor

Marjory Stoneman Douglas Building
3900 Commonwealth Boulevard
Tallahassee, Florida 32399-3000

David B. Struhs
Secretary

January 30, 2001

CERTIFIED MAIL RETURN RECEIPT REQUESTED

Mr. William C. Thomas, III
Vice President of Industrial Development & Operations
Conrad Yelvington Distributors, Inc.
Post Office Box 1686
Daytona Beach, Florida 32115

Re: Amended Application for an Air Construction Permit
Powerscreen Sand and Gravel Classifier: Draft Permit No.: 7770473-001-AC

Dear Mr. Thomas:

We received the original application for an air construction permit for a Powerscreen Chieftain 510 on April 19, 2000. The initial application indicated that the screener was to be employed as a relocatable facility at any on the applicant's aggregate storage and processing yards for screening and classifying sand and rock aggregates, at various storage yards owned or operated by Conrad Yelvington Distributors, Inc.(CYDI), throughout the state. This application was processed to a draft Air Construction Permit that was issued on August 11, 2000. In the final days of processing the application we discovered, during a telephone call, that the CYDI intended to use this screener for processing spent abrasive blasting media (ABM). This intended use was not indicated in the application. The spent ABM has the potential of containing toxic heavy metals and toxic chemical residues from paints. Rather than delay or deny the draft permit at that time, we included a paragraph prohibiting the processing of ABM or other hazardous material.

CYDI has never published the public notice that was included in the "Intent to Issue" package for 7770473-001-AC. Rather, CYDI sought to amend the application, and urge the Department to modify the draft Air Construction Permit. Assurances were to be provided that the spent abrasive material was not hazardous, that the proposed processing of ABM would not violate state or federal air pollution standards, that the ABM would not constitute a health hazard, to provide testing criteria for acceptable material, and a management plan for dust and unacceptable spent ABM material.

We agreed to allow you 60 days to amend the application (without additional fees).

Your letter transmitting Stephanie Brooks' undated letter and laboratory reports followed on October 2, 2000. We accepted these documents as an "amendment" to the application. Ms. Brooks made some emission calculations based on TCLP test results and AP 42 emission factors. These calculations were unacceptable because TCLP is not an appropriate laboratory test for determining potential air emissions. I deemed this amendment to the application insufficient and wrote a "Completeness Review and Request for Additional Information", which was mailed on October 16, 2000. I also provided technical reference material that I obtained from the Department's Division of Waste and from an EPA internet search site.

FLORIDA DEPARTMENT OF ENVIRONMENTAL PROTECTION

Department of Environmental Protection

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The certified mail return receipt card shows that you received the notice of completeness review and request for additional information on October 23, 2000.

More than 90 days have past since you received our completeness letter. The application has been in house 280 days, including our agreed extensions.

The Powerscreen Chieftain 510 is not permitted to operate at this time. The documents issued on August 11, 2000, do not authorize assembly, testing or operation of the facility. They only reflect the Department's intent to issue an Air Construction Permit, following (and conditioned upon) the publication of a public notice and resolution of any issues arising therefrom. The procedure for obtaining an Air Operation Permit requires the existence of a valid Air Construction Permit, a separate application and fee for the Air Operating Permit, as well as completion of compliance testing.

Rule 62-4.055(1) Florida Administrative Code provides:

> (1) Within thirty days after receipt of an application for a permit and the correct processing fee the Department shall review the application and shall request submittal of additional information the Department is authorized by law to request. The applicant shall have ninety days after the Department mails a timely request for additional information to submit that information to the Department. If an applicant requires more than ninety days in which to respond to a request for additional information, the applicant may notify the Department in writing of the circumstances, at which time the application shall be held in active status for one additional period of up to ninety days. Additional extensions shall be granted for good cause shown by the applicant. A showing that the applicant is making a diligent effort to obtain the requested additional information shall constitute good cause. Failure of an applicant to provide the timely requested information by the applicable deadline shall result in denial of the application.

Since we have had no response to our letter of October 16, 2000, requesting additional information, nor have we had any request for an extension to the 90 day response time, the Department will allow you thirty days from the receipt of this letter to provide all the information requested in the October 16 letter, or to indicate good cause why this time should be extended. Otherwise, the requested permit will be denied.

If you have any questions, please call me at (850) 921-9522.

Sincerely,

W. Leffler

William Leffler, P.E.
Permitting Engineer

Cc:
Stephanie S. Brooks, P.E., Brooks and Associates, Inc.
Clair Fancy, BAR
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Richard B. Tedder, Division of Waste Management

Best Management Practices for Waste Abrasive Blasting Media

August 1998

Timothy G. Townsend
University of Florida

State University System of Florida
FLORIDA CENTER
FOR SOLID AND HAZARDOUS WASTE MANAGEMENT
2207 NW 13 Street, Suite D
Gainesville, FL 32609

Report #98-8

BEST MANAGEMENT PRACTICES FOR WASTE ABRASIVE BLASTING MEDIA

Timothy G. Townsend, Principal Investigator
Jenna Jambeck Carlson, Graduate Research Assistant
Department of Environmental Engineering Sciences
University of Florida
Gainesville, FL 32611-6450
(352) 392-0846

August, 1998

ACKNOWLEDGEMENTS

The authors wish to thank the Technical Advisory Group for their assistance on this project: Tommy Addison, Allison Amram, Charles Bartlett, Mike Flynn, Mary Nogas, Frank Rea, Richard Rochelle, Bob Rupert, and Terry Tripp.

Thanks are also extended to the Florida Department of Environmental Protection for regulatory assistance in development of the Best Management Practices Document. The authors would like to recognize the Florida Center for Solid and Hazardous Waste Management for funding this research.

This report was prepared by Jenna Jambeck Carlson with research assistance from Allan Brantley, William Craven, Yong-Chul Jang, Brian Messick, Thabet Tolaymat, and William Weber.

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LIST OF FIGURES

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ABBREVIATIONS AND ACRONYMS

ABM	Abrasive Blasting Media
CFR	Code of Federal Regulations
DOT	Department of Transportation
EPA	Environmental Protection Agency
FDEP	Florida Department of Environmental Protection
FSCG	Florida Soil Cleanup Goal
SPLP	Synthetic Precipitation Leaching Procedure
TAG	Technical Advisory Group
TCLP	Toxicity Characteristic Leaching Procedure

ABSTRACT

Used abrasive blasting media is a solid waste produced by many industries including the military, transportation departments, ship maintenance facilities, and sandblasting contractors. The military and transportation departments are large enough to maintain organized management programs for this waste stream. Smaller operations, however, including ship maintenance facilities and sandblasting contractors are often unaware of proper management responsibilities. A research project was conducted to study several types of waste abrasive blasting media (ABM), with a special focus on waste ABM produced by ship maintenance facilities and sandblasting contractors.

The ABM waste stream was typically found to be non-hazardous. For the ship maintenance facility and sandblasting contractor waste, some groundwater guidance concentrations and risk-based direct exposure standards were exceeded. Metals that exceeded Florida's risk-based soil cleanup target levels (SCTL) in ship maintenance facility samples included arsenic, copper, and iron. Sample collected from the general contractor facilities did not exceed residential SCTLs. In leaching tests (using the Synthetic Precipitation Leaching Procedure), ship maintenance facility ABM waste exceeded groundwater guidance concentrations (GWGC) for zinc (a secondary standard), and occasional for copper, iron, and lead. Leaching from general contractor waste ABM was limited to iron (a secondary standard) and on rare occasion cadmium. Management options for their waste streams were reviewed.

This research also produced a Best Management Practices document for use by abrasive blasting industry professionals. The development of this document included input from industry professionals, regulators and consulting engineers. The information presented includes identifying proper regulatory requirements, environmental measurements, and management options.

EXECUTIVE SUMMARY

This report summarizes research conducted on solid waste produced by the abrasive blasting industry. Samples were collected from a variety of producers of abrasive blasting media (ABM) waste. This waste was examined in terms of total metal content as well as leachability of metals. The analytical results were compared to Florida's groundwater guidance concentrations and risk-based soil cleanup target levels. A "Best Management Practices" document was developed to assist regulators and the abrasive blasting industry in the management of this waste stream.

Background

Abrasive blasting is a process used by many industries to remove paint and other coatings from primarily metal surfaces. The solid waste produced contains the original abrasive material and any material that was present on the structural surface. The management of solid waste from abrasive blasting is a relatively new concern for many industries. This is especially true in cases where the media is non-hazardous in nature. In some cases it is not even recognized as a solid waste.

The largest generators of waste ABM include the ship maintenance industry, the transportation industry (bridge blasting), and military operations. Other generators include general sandblasting contractors, metal fabricators, autoshops and airports. The management of ABM waste can be challenging for both small and large generators. Generators must characterize the waste as hazardous or non-hazardous before it can be properly disposed or recycled. The regulations for generators of hazardous waste are well defined for most scenarios, but the proper management practices for non-hazardous ABM waste typically are not.

Because of the soil-like properties of this waste, some operations have allowed the material to remain on the job-site in a manner that the waste becomes incorporated as part of the existing site soil. This practice is not typically permitted under state regulatory requirements, and generators of abrasive blasting solid waste are going to face increased scrutiny as the management of nonhazardous industrial waste receives greater attention from the regulatory community. It is therefore essential that proper management practices be outlined for integrated management of abrasive blasting solid waste.

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. These constituents are composed of both organic and inorganic chemicals. 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.

The principal pigment in use today 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. The toxicity and regulation of this metal has required the phasing out of the use of lead for many applications. 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.

Research Methodology and Results

This document is the final report for the project "Best Management Practices for Waste Abrasive Blasting Media" sponsored by the Florida Center for Solid and Hazardous Waste Management. This research follows up a previous report written by the authors entitled "Disposal and Reuse Options for Spent Sandblast Grit." Previous research involved a compilation of existing literature, industry information, and regulatory waste characterization data. The abrasive blasting industry and the common types of abrasive blast media (ABM) were examined, data regarding chemical characterization were summarized, and management options were reviewed.

The research reported here involved the collection of additional chemical characteristic data. This characterization was performed by sampling various generators of waste ABM and analyzing the ABM for total metals concentration, as well as leachable metals concentration through the Toxicity Characteristic Leaching Procedure (TCLP), the Synthetic Precipitation Leaching Procedure (SPLP), and a leaching column study. Sample's locations are presented in Figure ES-1. The results of these analyses helped to characterize waste ABM and aided the development of the Best Management Practices (BMP) document.

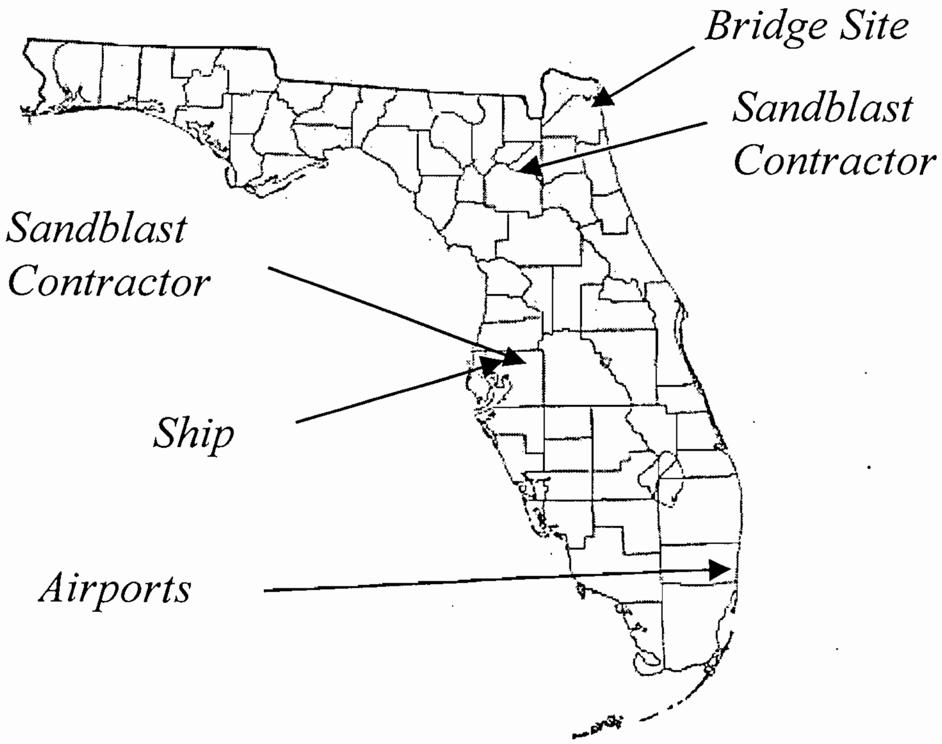

Figure ES-1. Sampling Locations

The ABM waste stream was typically found to be non-hazardous. For the ship maintenance facility and sandblasting contractor waste, some groundwater guidance concentrations and risk-based direct exposure standards were exceeded. Metals that exceeded Florida's risk-based soil cleanup target levels (SCTL) in ship maintenance facility samples included arsenic, copper, and iron. Sample collected from the general contractor facilities did not exceed residential SCTLs. The leachability of waste ABM must be considered in terms of potential groundwater contamination. The SPLP test, an assay used to simulate rainfall conditions, was used to examine the leachability of waste ABM samples collected. Lysimeter studies were also completed to further examine leaching characteristics. For the ship maintenance facilities, iron, copper, and zinc exceeded their respective groundwater guidance concentrations in some leachate samples. One sample exceeded the standard for lead. Iron also leached above the limits for the sandblasting contractor media. One sample of the contractor media leached above the standard for cadmium. Occasionally lead and cadmium exceeded a drinking water standard for both ship maintenance facility and sandblasting contractor waste. Table ES-1 and ES-2 summarize the analytical results for the ship maintenance facility and general contractor waste ABM, respectively. Results are presented in terms of possible exceedance of residential and industrial direct exposure SCTLs, and Florida Groundwater Guidance Concentrations.

Table ES-1. Potential Concerns with Ship Maintenance Facility Waste ABM

Metal	Direct Exposure Residential	Direct Exposure Industrial	Groundwater-Leaching
Arsenic	Yes	Possibly	No
Cadmium	No	No	No
Chromium	No	No	No
Copper	Yes	No	Possibly
Iron	Yes	No	Possibly
Lead	No	No	Possibly
Nickel	No	No	No
Selenium	No	No	No
Zinc	No	No	Yes

Table ES-2. Potential Concerns with Sandblasting Contractor Waste ABM

Metal	Direct Exposure Residential	Direct Exposure Industrial	Groundwater-Leaching
Arsenic	No	No	No
Cadmium	No	No	Possibly
Chromium	No	No	No
Copper	No	No	No
Iron	No	No	Yes
Lead	No	No	No
Nickel	No	No	No
Selenium	No	No	No
Zinc	No	No	Yes

Best Management Practices

Further development and input to the Best Management Practices document was provided by a technical advisory group (TAG). The TAG consisted of abrasive blasting industry professionals, Florida Department of Environmental Protection (FDEP) regulators, and consulting engineers. The TAG met throughout the research and discussed topics of concern to all parties involved. A Best Management Practices guide was drafted and reviewed by the TAG. TAG members made comments that were incorporated into the final document.

This research developed a management strategy outlining the steps that can be taken by a generator to properly manage waste ABM. The research studied several types of waste ABM, but concentrated on the ship maintenance facility and sandblasting contractor waste. The abrasive blasting media encountered during this research was typically non-hazardous. The FDEP file reviews also confirmed this. However, when paints with higher metal contents are blasted, the waste may take on the hazardous characteristic for toxicity. The rules for the management of hazardous waste must be followed and these are clearly stated in the Code of Federal Regulations.

When waste ABM is non-hazardous, other considerations may be made to assess the safety of human health and the environment. Direct exposure risk through ingestion, inhalation, and dermal contact may be considered. Direct exposure limits are typically risk-based numbers utilized by regulators in assessing the contamination of soil at a site or to regulate the placement of materials on the land. If waste ABM is in consideration of being placed on the land or allowed to accumulate on site in a manner where human contact may occur, the direct exposure risk must be assessed.

Because this waste stream does exceed some groundwater guidance concentrations, the production of leachate must be minimized. The best way to minimize leachate production is to not produce it in the first place. Leachate production may be prevented by covering the waste with a plastic cover or by keeping it under a roof or overhang. Storage on an impervious surface, like concrete is also recommended. Because direct exposure limits may also occasionally be exceeded, waste should not be placed in an area likely to result in human contact. Waste ABM may be disposed of in a lined landfill or recycled in a manner which will not produce leachate when the waste exceeds groundwater guidance concentrations. An excellent recycling option for the coals slag used media is at a cement kiln. The media contains minerals needed as feedstock in the cement-making process. Other recycling options include as aggregate in concrete or asphalt.

KEY WORDS

Abrasive Blasting Media

Sandblast Grit

Solid Waste

Hazardous Waste

Leachate

Toxicity Characteristic Leaching Procedure (TCLP)

Synthetic Precipitation Leaching Procedure (SPLP)

Leaching Columns

Beneficial Reuse

1. INTRODUCTION

1.1 OVERVIEW

This document is the final report for the project "Best Management Practices for Waste Abrasive Blasting Media" sponsored by the Florida Center for Solid and Hazardous Waste Management. This research follows up a previous report written by the authors entitled "Disposal and Reuse Options for Spent Sandblast Grit" (Townsend and Carlson, 1997). Previous research involved a compilation of existing literature, industry information, and regulatory waste characterization data. The abrasive blasting industry and the common types of abrasive blast media (ABM) were examined, data regarding chemical characterization were summarized, and management options were reviewed.

The research reported here involved the collection of additional chemical characteristic data. This characterization was performed by sampling waste ABM from various generators and analyzing these samples for total metals concentration, as well as leachable metals concentration using the Toxicity Characteristic Leaching Procedure (TCLP), the Synthetic Precipitation Leaching Procedure (SPLP), and a leaching column study. The results of these analyses helped to characterize waste ABM and aided the development of a *Best Management Practices* document.

Further development and input to the *Best Management Practices* document was provided by a technical advisory group (TAG). The TAG consisted of abrasive blasting industry professionals, Florida Department of Environmental Protection (FDEP) regulators, and consulting engineers. The TAG met throughout the research and discussed topics of concern to all parties involved. A Best Management Practices guide was drafted and reviewed by the TAG. TAG members made comments that were incorporated into the final document.

1.2 ORGANIZATION OF DOCUMENT

This report begins with a presentation of background information and an update of previous research in Chapter 2. Chapter 3 discusses sampling and analytical methodology. This chapter covers the locations sampled and the types of ABM encountered as well as how these wastes were generated. Chapter 4 presents the results of chemical analyses performed on the samples collected. The sample results for waste from ship maintenance facilities and sandblasting contractors have also been discussed in greater detail as part of a University of Florida Master of Engineering thesis regarding characterizing these two waste streams (Carlson, 1998).

The development of *Best Management Practices for Waste Abrasive Blasting Media* is discussed in Chapter 5. The actual document is contained in Appendix C. A final summary and a set of conclusions are presented in Chapter 6.

2. BACKGROUND

2.1 SUMMARY OF EXISTING INFORMATION

This project was a follow up and continuation of a previous project regarding disposal and reuse options for spent sandblast grit (Townsend and Carlson, 1997). The first project involved a compilation of existing literature, industry information, and regulatory waste characterization data. The abrasive blasting industry was discussed, the common types of ABM were examined, data regarding chemical characterization were summarized, and management options were reviewed. Pertinent sections of this previous work are reviewed here.

2.1.1 Abrasive Blasting

Abrasive blasting is a process used by many industries to remove paint and other coatings from primarily metal surfaces. The solid waste produced contains the original abrasive material and any material that was present on the structural surface. The management of solid waste from abrasive blasting is a relatively new concern for many industries. This is especially true in cases where the media is non-hazardous in nature. In such cases, waste ABM is many times not even recognized as a solid waste.

The largest generators of waste abrasive blasting media (ABM) include the ship maintenance industry, the transportation industry (bridge blasting), and military operations. Other generators include general sandblasting contractors, metal fabricators, autoshops, and airports. The management of ABM waste can be challenging for both small and large generators. Generators must characterize the waste as hazardous or non-hazardous before it can be properly disposed or recycled. The regulations for generators of hazardous waste are well defined for most scenarios, but the proper management practices for non-hazardous ABM waste typically are not.

Because of the soil-like properties of ABM waste, some operations have allowed the material to remain on the job-site in a manner that the waste becomes incorporated as part of the existing site soil. This practice is not typically permitted under state regulatory requirements, and generators of abrasive blasting solid waste are going to face increased scrutiny as the management of nonhazardous industrial waste receives greater attention from the regulatory community. It is therefore essential that proper management practices be outlined for integrated management of abrasive blasting solid waste.

2.1.1.1 Common Media Used and Applications

The two most common types of media encountered during this study were silica sand and coal slag. These two types of media are very good for general all-purpose blasting applications. These media are sold in several gradations for lighter to heavier blasting processes. Other types of media that are sometimes used include steel shot, plastic, and biodegradable media like walnut shells. Table 2-1 shows the most common types of media and their uses, as well as the industries that typically handle the blasting operation.

Table 2-1. Applications of Abrasive Blasting Media

APPLICATION	MEDIA	INDUSTRY
Military Ships and Airplanes	Coals Slag, Plastic, Glass Bead	Military
Bridges	Steel Shot/Grit, Coal Slag	DOT (may sub-contract but still oversees mgmt.)
Ships/Barges	Coal Slag, Copper Slag	Ship Maintenance Facilities/Marinas
Airplanes/Parts	Plastic, Glass Bead	Airplane Maintenance Facility
Autos	Silica Sand, Plastic	Auto Body Shops
Semi-trailers	Silica Sand	Sandblasting Contractor
Scaffolding	Silica Sand	Sandblasting Contractor
Heavy Machinery	Silica Sand	Sandblasting Contractor
Water Tanks/Towers	Silica Sand, Coal Slag	Sandblasting Contractor
Railroad Cars	Silica Sand, Coal Slag	Sandblasting Contractor/Rail Facility

2.1.2 Concern with Waste ABM

In the past, waste ABM may have remained on the blasting site, typically on the ground where metals and other contaminants could leach off and/or accumulate. This practice is not allowed under typical regulatory policies if the waste may cause the contamination of groundwater or cause a human health risk through exposure. All colored coatings contain pigments, and most pigments contain heavy metals. These metals inevitably become part of the waste ABM. Heavy metals are sometimes even found in unused media such as coal slag. The proper management of this waste is therefore necessary. Because of the soil-like properties of waste ABM, it many times can be mistaken as a soil, which it is not. This material is a solid waste that must be properly handled according to federal, state, and local regulations.

2.1.2.1 Origination of Metals in ABM Waste

As an explanation of why heavy metals may occur in unused media such as coal slag, a brief discussion on the properties of coal slag follows. Other media, including copper slag and nickel slag, may also contain heavy metals inherent to the media. 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 parts per million 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 the 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 thus play a role in determining management requirements.

Even though some types of 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. These constituents include both organic and inorganic chemicals. Typically the organic components serve as the binders and solvents, but additives, pigments and extenders may also be synthetic organic compounds. The inorganic components, usually composed of a metallic compound, include the primary pigments, additives, and extenders (Lambourne, 1987).

The principal pigment in use today is titanium dioxide (a white pigment made popular because of fashion concerns). In the past, two commonly used pigments were lead silicate and lead sulfate (Lambourne, 1987). The toxicity of lead has required the phasing out of its use 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 used in specific industrial applications where needed, but 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 as a biocide (Munger, 1984). The butyltin compounds remain in use and 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* (United States Code, 1988) limits the use of tributyltin to ships over 25-ft in length (except for aluminum hulls) and limits the overall leaching rate of a coating. However, there are currently no direct exposures, primary or secondary drinking water standards for these organic compounds.

Table 2-2 presents 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.

Table 2-2. 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

N/A = Not Applicable

2.1.3 Literature Review Findings

The literature review from the previous report on disposal and reuse options for spent sandblast grit (Townsend and Carlson, 1997) found that many recycling options are currently being utilized or explored for this waste stream.

The most attractive option for recycling nonhazardous spent coal slag and silica sand ABM is use for the production of Portland cement (U.S. EPA, 1994). Cement is made from limestone (or other sources of calcium carbonate), silica, aluminum, and iron oxides. These minerals may be provided by clay, diatomaceous earth, inorganic wastes, or other sources, and sometimes has to be imported. Typical Portland Cement is made up of 22% silica oxide, 65% calcium oxide, 6.5% aluminum oxide, and 6.5% iron oxide (Hagerman 1997).

The cement mix percentages may come from any material containing the required constituents. Spent coal slag and silica sand ABM can be used in this process because of their high aluminum, iron, and silica components. There is a profit motive for the cement kilns to accept waste ABM. The kilns get paid to take a feedstock that would normally have to be purchased, and the waste generator pays less than landfill tipping fees to dispose of the waste ABM. One issue, which must be addressed for this recycling option, is the storage of the waste ABM. The cement manufacturer must comply with all of the required management practices for storage as the generator does. This may require storing waste ABM on an impervious pad. Storage issues will be reviewed later in discussions of *Best Management Practices*.

Waste ABM may also be recycled as aggregate in the production of asphalt concrete and portland cement concrete. The waste ABM may be substituted for the normally used aggregate in entirety, or more likely as a percentage of the aggregate used. Some properties, including ABM shape and metals content, may make this recycling process less favorable (Heath et al. 1996). This option was most commonly explored in the literature. In North Carolina a case study was completed that successfully used blasting sand in asphalt concrete (Medford, 1989). A field demonstration of "Recycling

Spent Sandblasting Grit into Asphaltic Concrete" was also completed by the Naval Facilities Engineering Center in Port Hueneme, California (Means et al. 1996).

Recycling and stabilization of hazardous and nonhazardous spent blasting sand was explored in the literature by Salt et al. (1996) in "Recycling Contaminated Spent Blasting Abrasives in Portland Cement Mortars," along with Brabrand and Loehr in "Solidification/Stabilization of Spent Abrasives and Use as Nonstructural Concrete." Hazardous waste minimization options were examined in the literature (Sowell, 1989) along with using blasting additives to lower the production of hazardous waste (Vincent 1995) and to increase recycling options.

Plastic media may be recycled once it has been used. Companies around the United States such as *U.S. Technology* located in Ohio lease plastic media to ABM users. The media is shipped to the user in drums and the spent media is returned to these same drums and shipped back to U.S. Technology for recycling. The plastic media can be recycled into counter tops and vanities. It has been proposed that organic ABM such as walnut shells and plastic media may be burned for their fuel value.

2.1.4 Regulatory File Review Findings

A file review was completed of the district solid waste sections of the Florida Department of Environmental Protection (FDEP) as part of the previous report (Townsend and Carlson, 1997). Added to this compilation of analytical data was some district hazardous waste section FDEP information. A current summary of the entire file review data follows.

2.1.4.1 Updated Chemical Characteristic Database

The types of blasting applications encountered included shipyards, bridge blasting, autoshops, railcar yards, and airports. While a few instances of organic chemical testing were found, heavy metals were the primary pollutants of concern. TCLP was performed in some cases, and total metal analyses were conducted in others.

Combining all of the FDEP data resulted in a total of 155 analytical results, with 44% of the results from one ship blasting site. Out of these tests, only 8 (or 5%) found the waste ABM to be hazardous by federal standards. Half of these samples were hazardous because the TCLP lead concentrations were above the 5 mg/l limit, and the other half were over the 1 mg/L limit for Cadmium.

2.1.5 National Survey Findings/Management Practices

In a survey of all fifty state regulatory agencies to find any specific policies pertaining to spent ABM waste, most indicated that applicable hazardous waste regulations would apply. Seven states (14% of respondents) have either a special waste policy or recommendations, management practices, or specifically regulate the disposal and recycling of waste ABM. For example, Virginia has a "Discarded Sand Blast Grit Policy." California has its own hazardous waste regulations and policies regarding

"Requirements for Recyclable Materials Placed on the Land." Lastly, Michigan has "Recommendations for Abrasive Blasting of Water Towers and Other Steel Structures."

A phone survey of Florida Counties was also conducted. Both Dade and Broward Counties have Best Management Practices for Marine Facilities which include the management of abrasive blasting media at these facilities.

2.2 BEST MANAGEMENT PRACTICES RESEARCH

Technical advisory group meetings were held throughout the duration of this project. A best management practices document was produced which included input from industry professionals, regulators, engineering consultants, as well as private companies involved in the management of this waste stream.

2.2.1 Industry Input

Industry concerns varied with the type of industry utilizing abrasive blasting. The authors attended a health and safety officer meeting for shipping industry personnel at the Port of Tampa to gather input on management practices. Concerns expressed by port officials included the fact that inconsistent regulations were imposed by governing regulatory agencies. The port officials expressed a desire to manage their waste in the correct manner, but received varied input as the best way to do this. The *Best Management Practice*s guide was therefore developed with the goal of providing a tool for use by both regulators and industry. The guide would attempt to outline consistent policy and would help make sure the industry is aware of all pertinent and relevant regulations.

The general contractor industry expressed these and other concerns. General sandblasting contractors are often small businesses. A goal was therefore also established for the BMP document to identify the necessary testing procedures for generators of waste ABM. Any useful information on how to specify laboratory procedures and appropriate detection limits were also targeted.

2.2.2 Regulatory Input

Regulators from the Florida Department of Environmental Protection were included as part of the Technical Advisory Group, along with engineers and abrasive blasting industry professionals. These individuals all provided input into the format of this research. A discussion of regulatory practices in this industry follows. This discussion is also based on a review of applicable regulations and literature regarding waste management and reuse.

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 according to federal regulations. Waste ABM is not a listed hazardous waste and the characteristic most likely to be encountered that would classify the waste as hazardous is the toxicity characteristic.

2.2.2.1 Hazardous Characteristic

The toxicity characteristic leaching procedure (TCLP) is the assay prescribed by the EPA to determine whether a solid waste is hazardous by toxicity characteristic (U.S. EPA, 1992). In this test, a solid waste is extracted using an acetic acid based leaching solution, with a pH that is dependent on the alkalinity of the waste (2.88 or 4.93). The leaching solution is designed to simulate acids resulting from anaerobic conditions within a MSW 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 by the toxicity characteristic. Past research has indicated that organic compounds are not usually encountered when dealing with waste ABM (Townsend and Carlson, 1997).

2.2.2.2 Direct Human Exposure Limits

A non-hazardous waste is still a solid waste and must be managed appropriately. Waste ABM tested as nonhazardous may be disposed in a lined sanitary landfill without additional testing. The issue becomes more complicated when waste is accumulated, disposed on-site, land applied, or disposed in an unlined facility. In this case, the waste should be evaluated to assess possible risk to human health through direct exposure. This is more of a concern for situations when the waste is disposed of by land application and human contact is likely, or where during a facility's operation (or in the future) human contact is likely. Direct exposure includes ingestion, dermal contact, and inhalation.

To assess the direct exposure risk of waste ABM, the total metal concentration is measured (mg/kg). The heavy metal concentrations in samples of waste ABM may be compared to risk-based exposure standards to determine what reuse or disposal options are appropriate. The Florida Department of Environmental protection has developed *Soil Cleanup Target Levels* (SCTLs, formerly known as Soil Cleanup Goals). The SCTLs were designed for assessment of contaminated sites contaminated sites contaminated sites contaminated sites and were developed using a risk-assessment methodology. This risk-based methodology was conducted using procedures described in a document published by the U.S. EPA (U.S. EPA, 1996). Table 2-3 contains Florida SCTLs for heavy metals for both residential and industrial reuse settings.

Direct exposure limits are a set of risk-based concentrations, but they are goals and not regulations. These limits are tools that can be used from several perspectives, including assessing the contamination or cleanliness of a site, as well as for determining boundaries for land application of materials.

2.2.2.3 Impact on Groundwater

In addition to direct exposure to humans from chemicals in waste ABM, the risk to groundwater through leaching must also be evaluated. This can be done through two ways, either through a theoretical leaching model based on total metal concentration or

Table 2-3. Risk-Based Standards for Total Metal Concentrations.

Metal	Residential SCTL (mg/kg)	Industrial SCTL (mg/kg)
Arsenic	0.8	3.7
Barium	105	87,000
Cadmium	75	1300
Chromium	290	430
Copper	105	12,000
Iron	23,000	490,000
Lead	500	920
Mercury	3.7	28
Nickel	105	28,000
Selenium	390	10,000
Silver	390	9,100
Zinc	23,000	560,000

through leaching tests which measure the metal concentration a material will release in under laboratory-simulated conditions. In either case, established groundwater guidance concentrations are used to assess acceptable risk.

The theoretical model will be discussed first. First, an appropriate groundwater standard or guidance concentration was multiplied by a dilution attenuation factor (DAF) of 20.To obtain a target leachate concentration, this DAF was selected by a "weight of evidence" approach by EPA (U.S. EPA, 1996). This DAF accounted for dilution and attenuation in the environment for a 0.5-acre area. A total metal concentration was then calculated that would result in a pore water leachate equal to target leachate concentration. The model for this calculation incorporated a partition coefficient for each compound of interest. Figure 2-1 is the equation used by the U.S. EPA to calculate the total metal concentration from the target leachate concentration. Florida has adopted this approach as well as the default values associated with it.

$$C_t = C_w\left(K_d + \frac{\theta_w + \theta_a H'}{\rho_b}\right)$$

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 (FL default 0.3)
θ_a=air-filled soil porosity (FL default 0.13)
ρ_b=dry soil bulk density (FL Default 1.5 kg/L)
H'=dimensionless Henry's Law Constant (H-atm-m^3/mol x 41(Conversion Factor))

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 environmental factors. 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, 1996). The use of these theoretical values, especially for a waste material, should be viewed with these uncertainties in mind.

The second method to determine potential risk to groundwater is through batch leaching tests, which simulate the leaching of materials in environmental conditions. The concentration of a chemical in the leachate produced by the leaching test is compared to the appropriate groundwater standard or guidance concentration. If the measured concentration is greater than the appropriate regulatory level, the waste is considered to present a risk to groundwater.

Although the TCLP test is primarily used to determine hazardous characteristics, it is sometimes used by states to determine the potential impact of a waste on groundwater when the waste is stored or disposed in non-landfill conditions (U.S. EPA, 1992). 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 simulates rainfall and is less aggressive than the TCLP solution, all other aspects of the test remain the same as the TCLP test. Table 2-4 contains Florida's groundwater guidance concentrations and theoretical soil target levels (for leaching) for twelve metals.

Table 2-4. Guidelines for Leachable Metal Concentrations.

Metal	FL Groundwater Guidance Concentration (ug/L)	FL Theoretical Leach. (mg/kg)
Arsenic	50	29
Barium	2,000	1,600
Cadmium	5	8
Chromium	100	38
Copper	1,000	-
Iron	300	-
Lead	15	-
Mercury	2	23
Nickel	100	130
Selenium	50	5
Silver	100	34
Zinc	5,000	12,000

3.SAMPLE COLLECTION, ANALYSIS & METHODOLOGY

Samples were collected using methodology outlined in the FDEP standard operating procedures (Section 4.0) and as outlined in the UF Solid and Hazardous Waste Research Group Comprehensive Quality Assurance for Field Sampling (COMPQAPP# 960218). Since metals were the primary pollutant of interest, nitric acid rinsed plastic containers were used. The sites where samples were collected are outlined in Table 3-1.

Table 3-1. ABM Waste Sample Collection

Site	Date Sampled	Media	Description	Samples Collected
Commercial Building Renovation Site	8/18/97	Coal Slag	Painted Highway Sign Posts and Building	2
Bridge Blasting Site	6/11/97	Coal Slag	Contained Blasting Site	3
Airport Maintenance Shops (1-3)	6/23/97	Sand/Plastic	Blast Cabinet Waste	3
Ship Blasting Site	9/4/97	Coal Slag	Dry Dock Ship Blasting	2
Ship Blasting Sites (2-4)	1/9/98	Coal Slag	Dry Dock Ship Blasting	26
Sandblasting Contractor Sites (2-3)	1/8/98	Silica Sand	Heavy Machinery	10
Sandblasting Contractor Site (4)	1/19/98	Silica Sand	Scaffolding	5

Samples of unused ABM were also obtained for analysis. Samples of the materials were purchased in 50 lb bags from Standard Sand and Silica. As discussed previously, in some cases metals may exist in the unused ABM which could possibly classify the material as hazardous (very rare) or limit reuse options. Table 3-2 presents the unused media obtained for analysis.

Table 3-2. Unused Media

UNUSED MEDIA
Silica Sand
Coal Slag
Garnet
Starblast
Steel Shot
Glass Bead
Aluminum Oxide

3.1 CHARACTERIZATION OF ABM WASTE

The previous report was a compilation of existing data from the literature and regulatory files (Townsend and Carlson, 1997). A preliminary characterization of raw and used abrasive blasting media was completed on this available data. To further this characterization, used abrasive blasting media samples were collected from a variety of sites throughout the state of Florida. To obtain a variety of samples, the sites were selected based on the type of media used and blasting operation employed.

3.1.1 Sites Sampled

The sites sampled not only varied in geographic location, but also varied by industry and types of media utilized. Samples were obtained from airport facilities, a Department of Transportation bridge blast site, ship blasting sites, and general contractor sites. Figure 3-1 is a map of locations sampled throughout Florida.

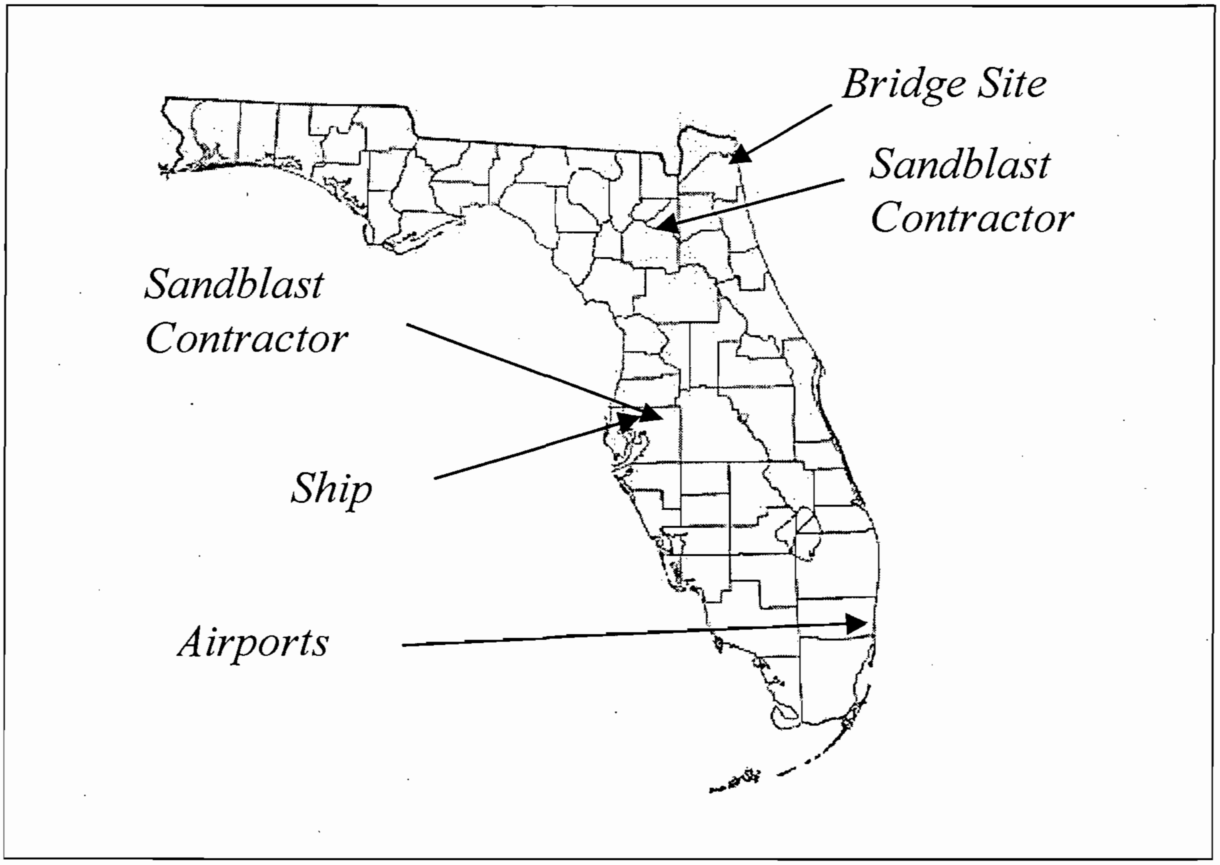

Figure 3-1. Sampling Locations

3.1.1.1 Airport Waste ABM Site

On June 23, 1997, three separate airport maintenance facilities at a small airport were sampled. One sample was collected from each site and thought to be representative of the waste generated at that site. Each site utilized a blast cabinet where media was recycled and reused until it was spent. The media used included plastic media and silica sand. The equipment cleaned with abrasive blasting media consisted of small airplane parts.

3.1.1.2 Bridge Blast Waste ABM Site

On June 11, 1997 a Florida Department of Transportation bridge maintenance site was sampled. The waste pile on site was a small circular pile 10 feet in diameter and 4 feet in depth at the center. Three samples were taken from three different sections around the pile at the center of each side. The media used at this site was coal slag media. The storage pile was located away from the blasting area and kept covered by a plastic sheet.

3.1.1.3 Sandblasting Contractor Site 1

This general contractor site was sampled on August 18, 1997. The contractor was blasting a commercial site which consisted of highway sign posts and the side of a painted building. Two composite samples were obtained from this site. The first sample was taken from under the three sign posts and the other was taken from along the entire side of the building where waste ABM was present. The media utilized at this site was coal slag.

3.1.1.4 Sandblasting Contractor Site 2

This site was sampled on January 8, 1998. This site was a sandblasting operation site with all blasting taking place out-of-doors. The primary media utilized was silica sand. The site was approximately two acres square. A total of six samples were collected from random locations in the pile. Samples were collected in 3.5 gallon containers.

3.1.1.5 Sandblasting Contractor Site 3

The third general contractor site sampled on January 8, was a site which blasted heavy machinery in a large holding bay with a concrete floor. The media used was silica sand. The bay was approximately 20 feet wide by 40 feet long with used grit piled in each corner. A total of four samples were obtained, one from each corner. The volume of sample taken was a 5 gallon container.

3.1.1.6 Sandblasting Contractor Site 4

The final general contractor site sampled on January 20, used silica sand and blasted out-of-doors. A building was under construction to house objects for blasting in the future. The area in which blasting took place was a 10 feet by 15 feet square, although some amount of media was spread over the entire site. The main blasting area was sampled for a total of five samples, one from each corner and one in the middle. The media utilized at this site was silica sand. The volume of each sample was approximately the volume of a 3.5 gallon container.

3.1.1.7 Ship Blast Site 1

On September 4, 1997, a ship blast site with a 50-ton stockpile of coal slag media waiting to be shipped to a cement kiln for recycling was sampled. The pile was approximately 50 feet long, 15 feet wide, and 10 feet deep. Two composite samples were collected in 5-gallon containers by sampling eight times around the entire pile. The top waste ABM material was removed and samples were taken from approximately 1.5 ft. deep. On January 9, 1998, this site had another smaller pile also waiting to be recycled at a cement kiln. This pile was about 30 tons and 40 feet long, 12 feet wide, and 10 feet deep. A total of twelve samples were collected at this time. Six samples were taken from around the pile, with a duplicate sample taken at each sample area. The samples were collected in 3.5-gallon containers.

3.1.1.8 Ship Blast Site 2

This ship blast site was sampled on January 9, 1998. The stockpile was approximately 60 tons, and not of uniform shape. Six samples were collected from this site in 3.5-gallon containers. The samples were collected from random areas around the entire pile. The media utilized at this ship blasting site was coal slag.

3.1.1.9 Ship Blast Site 3

This ship blast site consisted of a few stockpiles of media in a storage area adjacent to the working area. Two piles were sampled in this storage area. Six samples were taken from a 40-ton pile and two composite samples were taken from a 20-ton pile. The volume of each sample collected was approximately 3.5 gallons. Grass and plants were visible growing on these piles of media. The media utilized at this site was coal slag.

3.2 ANALYSIS OF WASTE ABM

The waste ABM was tested for both total metal concentrations and leachable metal concentrations. These metal concentrations were then compared to both state and federal regulatory limits and goals. The total concentrations (mg/kg) of various metal species were analyzed using standard digestion techniques followed by analysis of an atomic absorption spectrophotometer. Leaching was evaluated using both batch tests and column tests (see Section 3.3).

The two primary batch leaching methodologies used were the toxicity characteristic leaching procedure (TCLP) and the synthetic precipitation leaching procedure (SPLP). The TCLP test is the assay prescribed by the EPA to determine whether a solid waste is hazardous by toxicity characteristic in this procedure. A 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 leaching solution is an acetic acid based solution, with a pH dependent on the buffering capacity of the waste (2.88 or 4.93). The mixture 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). The TCLP leaching solution is designed to simulate anaerobic conditions within a landfill.

Although the TCLP test is primarily used to determine hazardous characteristics, it is sometimes used to determine the impact of a waste on groundwater when the waste is stored or disposed in nonlandfill conditions. A more suitable test for this scenario is SPLP. The SPLP assay uses a leaching solution 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. Other than the leaching solution, all other aspects of the test remain the same as the TCLP test.

3.3 CHEMICAL ANALYSIS

Chemical analysis of ABM samples and the leachate produced from them were conducted in the UF Environmental Engineering Science Solid and Hazardous Waste Laboratory (COMPQAPP# 960218). The methods used for the digestion and analysis of the samples are presented in Table 3-3 (U.S. EPA, 1986). Samples were analyzed on a Perkin Elmer 5100 atomic absorption spectrophotometer equipped with a flame and a graphite furnace. In addition to analysis for heavy metals, the leachates from the column tests were analyzed for a number of general water quality parameters (Table 3.3).

Table 3-3. Analytical Methods

Analysis	Method #
TCLP Extraction	EPA 1311
SPLP Extraction	EPA 1312
Total Metals Digestion	EPA 3050
Leachate Digestion (Flame)	EPA 3010
Leachate Digestion (Furnace)	EPA 3020
Alkalinity	Stnd. Method 2320
Anions	Stnd. Method 9056
Cations	EPA 300.7
Conductivity	Stnd. Method 2510
Dissolved Oxygen	Stnd. Method 4500-OG
pH	Stnd. Method 4500
Oxidation Reduction Potential	Stnd. Method 2580B
Total Dissolved Solids	Stnd. Method 2540C
Nonpurgeable Organic Carbon	Stnd. Method 5310B

APHA, 1995 U.S. EPA, 1986

3.4 LEACHING COLUMNS (LYSIMETERS)

To further investigate the leaching mechanisms of waste ABM, leaching columns, commonly called lysimeters, were filled with ABM from four different sites. Two other columns were filled with the raw media to observe background metal concentrations from unused media. A blank column, with only the drainage material was also used in the experiment to make sure no contamination came from the gravel or the column. Figure 3-2 is a diagram of a filled lysimeter.

3.4.1 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 3 ft.) was placed on top. The gravel served as drainage material for the leachate so that it was not stored in the waste stream after it filtered through the column. The lysimeters were approximately 3.5 ft tall and 6 inches in diameter.

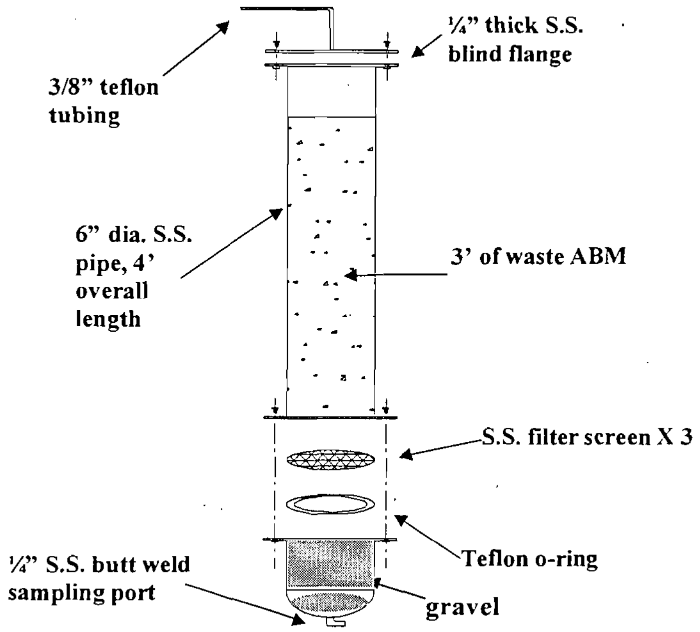

Figure 3-2. Diagram of Lysimeter Apparatus (Brantley, 1998)

The lysimeters were constructed 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. Mixing a bowl of waste from each sample container formed composite samples. These bowls were weighed separately and the total weight of each lysimeter recorded. Table 3-4 presents the lysimeter number and the type of sample contained in each. Sub-samples of approximately 300 g were taken from the waste as it was loaded into the columns. These sub-samples were utilized for other tests including total metals analyses.

Table 3-4 Lysimeter Sample Information

Lysimeter	Site	Sample	Sample Wt. (kg)	Bulk Density (kg/m^3)
1	SM-A	Coal Slag	26	1477
2	SM-ADuplicate	Coal Slag	27	1495
3	SC-B	Silica Sand	28	1591
4	SM-B	Coal Slag	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

3.4.2 Lysimeter Leaching

Rainfall conditions were simulated in the lysimeter by adding 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 50 ml per minute, which was equivalent to 5 cm of total rainfall over the surface area of the waste. Every other day before the new SPLP solution was added, the leachate produced from the previous addition was drained. The volume of leachate was recorded and general water quality 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 nonpurgeable organic carbon (NPOC) and cation analysis.

4. RESULTS

The results of the samples analyzed are presented in chronological order. The first set of analyses (preliminary characterization) included all of the samples collected during 1997, including unused media. These samples were tested for four metals of highest concern: lead, zinc, cadmium, and chromium. Tables summarizing the results as well as a discussion follows.

The second set of analytical results are presented in terms of specific types of ABM, where the results are presented followed by a discussion. These results are from the compilation of ship maintenance facility data and sandblasting contractor site data (Carlson, 1998). These two industries were examined closer because little was previously known about these two particular ABM waste streams.

Following the discussion of the ship maintenance facilities and sandblasting contractor sites, the lysimeter (leaching column) data is presented. The lysimeter experiment further examined the leaching mechanisms of the two waste streams. The column leaching study results are then compared to the batch results from both the TCLP and SPLP leaching tests.

4.1 PRELIMINARY CHARACTERIZATION: TOTAL METAL AND LEACHING RESULTS

The results for the first set of analyses are summarized in Tables 4-1 through 4-4. These tables include total metal results as well as batch leaching results for TCLP and SPLP (when completed). Leaching tests that were not completed are not presented in the table. The leaching percentage is calculated from the percentage of metal concentration leached when compared to the total metal concentration.

Table 4-1. Analytical Results for Lead

Sample	Total Lead (mg/kg)	TCLP Leachate (mg/L)	SPLP Leachate (mg/L)	% Leaching TCLP	% Leaching SPLP
Black Beauty*	<50	<1.0	<0.010	-	-
Glass Bead*	<50	<1.0	0.180	-	-
Aluminum Oxide	<50	<1.0	<0.010	-	-
Starblast*	<50	<1.0	<0.010	-	-
Steel Shot*	67	<1.0	<0.010	<30	<0.30%
Silica Sand*	<50	<1.0	<0.010	-	-
Garnet*	<50	<1.0	<0.010	-	-
Bridge Blast /A	182	<1.0	-	<11	-
Bridge Blast /B	233	<1.0	-	<8.6	-
Bridge Blast /C	215	<1.0	-	<9.3	-
Airport 1	102	<1.0	-	<19	-
Airport 2	1,525	30	-	39	-
Airport 3	238	6	-	50	-
GC / A	-	-	<0.010	-	-
GC / B	-	-	0.022	-	-
Ship Blast /A	-	-	<0.010	-	-
Ship Blast /B	-	-	<0.010	-	-

Table 4-2. Analytical Results for Cadmium

Sample	Total Cadmium (mg/kg)	TCLP Leachate (mg/L)	% Leaching TCLP
Black Beauty*	<5	<0.10	-
Glass Bead*	<5	<0.10	-
Aluminum Oxide*	<5	<0.10	-
Starblast*	<5	<0.10	-
Steel Shot*	<5	<0.10	-
Silica Sand*	<5	<0.10	-
Garnet*	<5	<0.10	-
Bridge Blast /A	<5	<0.10	-
Bridge Blast /B	<5	<0.10	-
Bridge Blast /C	<5	<0.10	-
Airport 1	3200	166	103%
Airport 2	50	1	40%
Airport 3	11.6	0.45	77%

*Unused Media

Table 4-3. Analytical Results for Chromium

Sample	Total Chromium (mg/kg)	TCLP Leachate (mg/L)	% Leaching TCLP
Black Beauty*	174	<1.0	<11
Glass Bead*	<50	<1.0	-
Aluminum Oxide	<50	<1.0	-
Starblast	<50	<1.0	-
Steel Shot	1476	<1.0	<2
Silica Sand*	<50	<1.0	-
Garnet*	67	<1.0	<30
Bridge Blast /A	159	<1.0	<13
Bridge Blast /B	185	<1.0	<11
Bridge Blast /C	175	<1.0	<12
Airport 1	1250	21	34
Airport 2	93	<1.0	<22
Airport 3	<50	<1.0	-
GC / A	<50	<1.0	-
GC / B	<50	<1.0	-
Ship Blast /A	<50	<1.0	-
Ship Blast /B	55	<1.0	<36

*Unused Media

Table 4-4. Analytical Results for Zinc

Sample	Total Zinc (mg/kg)	TCLP Leachate (mg/L)	SPLP Leachate (mg/L)	% Leaching TCLP	% Leaching SPLP
Black Beauty*	58	<0.1	-	<9%	-
Glass Bead*	42	0.87	-	17%	-
Aluminum Oxide*	<5	<0.1	-	-	-
Starblast*	<5	<0.1	-	-	-
Steel Shot*	41	<0.1	-	<12%	-
Silica Sand*	20	<0.1	-	<25%	-
Garnet*	21	<0.1	-	<24%	-
Bridge Blast /A	28,025	588	-	42%	-
Bridge Blast /B	37,280	597	-	32%	-
Bridge Blast /C	35,528	595	4.2	33%	0.23
Airport 1	3100	62	7.5	40%	4.8
Airport 2	99	1.9	<0.05	38%	<1.0
Airport 3	47	1.5	0.430	64%	18

*Unused Media

As discussed earlier, previous research indicated that waste ABM is typically non-hazardous. The analytical results above are similar to data found in the FDEP file search. The three airport maintenance samples were hazardous (two for lead, one for cadmium, and one for chromium). Half of the hazardous samples in the FDEP file search were from airport maintenance shops, which were hazardous for cadmium. The characteristics shown by these wastes are a product of the materials blasted. The waste was smaller in size and powder-like. This ABM was likely cycled through the blast cabinet several times, possibly concentrating the metal contaminants. These wastes were stored in drums at each site.

For the four metals analyzed, the risk based goals for clean soil were not exceeded for almost all of the samples. In all but one case, the hazardous wastes were over the residential limits for the metals that caused them to be hazardous. The bridge blast samples contained high amounts of zinc, which were just over the residential cleanup goal, but lower than the industrial cleanup goal. This waste was contained on site in a covered area before it was taken for proper disposal. The ship blast waste and raw materials did not contain high amounts of total metals for lead, cadmium, chromium, or zinc.

Regulators commonly compare SPLP sample leaching to groundwater standards because the test simulates leaching in non-landfilled conditions. A few SPLP samples analyzed for lead were over the 0.015 mg/L limit, along with the samples with high TCLP leaching metals. All of the TCLP and SPLP samples analyzed for zinc remained below the ground water guidance concentration of 5,000 mg/L. Analyses presented in the next section provide a more detailed look at leaching of waste ABM compared with ground water limits.

The percent leaching for metals in the TCLP analyses varied between 17 and 77 percent. This is a wide range of leaching values that may depend on the size of waste, concentration of contaminants, the differing leachability of some metals, or other characteristics of the waste. The SPLP samples analyzed leached between 0.23 to 18 percent. These leaching percentages varied somewhat, but were similar to the ranges seen in future sections with the more extensive batch and lysimeter studies. The SPLP samples analyzed leached less than the TCLP procedure on the same sample. These results coincided with the data for the second set of batch tests.

4.2 RESULTS AND DISCUSSION OF SHIP MAINTENANCE FACILITIES

4.2.1 Results

The results presented here include the tests to determine if the waste ABM samples from the ship blasting facilities were hazardous or not (TCLP), the tests used to assess the leachability of the waste in the natural environment (SPLP), and the results of total metal content of the waste.

4.2.1.1 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 4-5 contains the TCLP limits and results from this study. All of the samples tested were below the hazardous waste leaching limit and were therefore non-hazardous for the toxicity characteristic.

Table 4-5. 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

4.2.1.2. TOTAL METALS

Table 4-6 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 some data sets were high and variable so a log transformation was performed. The transformation was performed to make the variances uniform to facilitate future comparisons (Berthouex and Brown, 1994). The geometric means and standard deviations are used when the distributions were lognormal. Figures 4-1 through 4-4 show the histograms for the distributions of zinc, lead, copper, and iron. Lognormal distribution lines are plotted on the zinc, lead, and copper figures for comparison. A normal distribution line is plotted on the iron histogram for comparison.

Table 4-6. 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

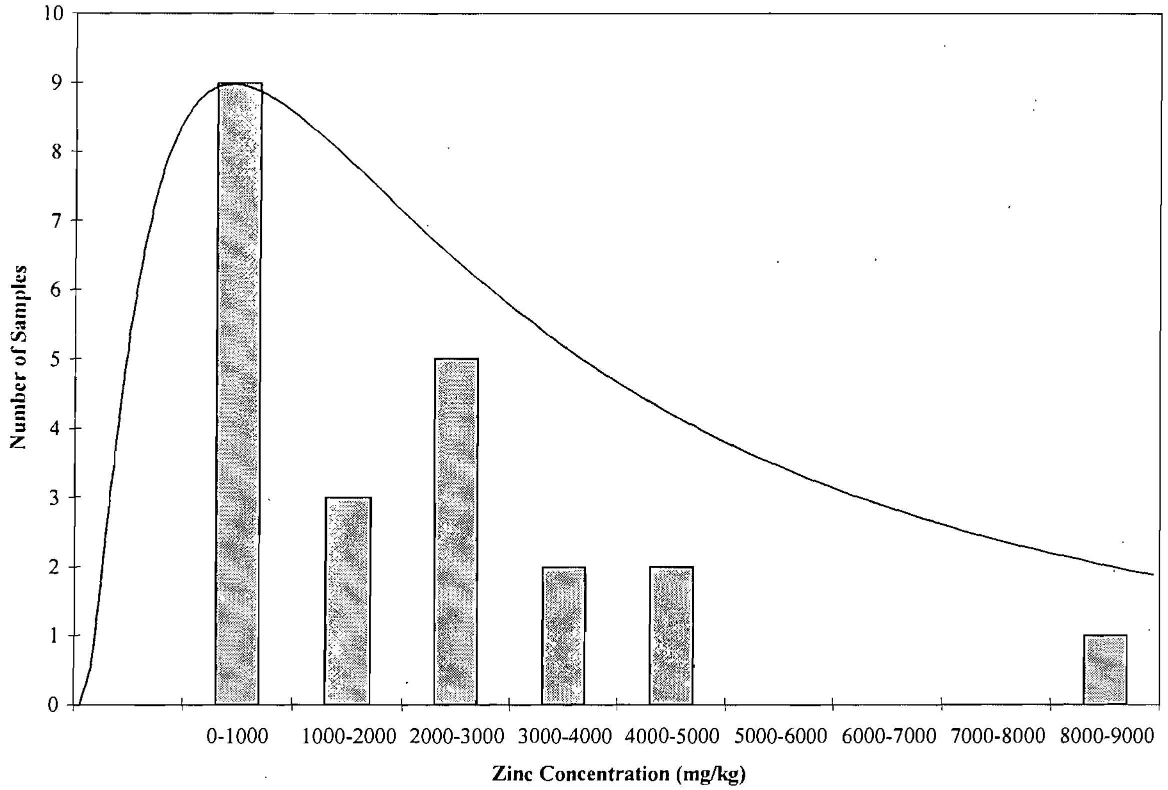

Figure4-1. Zinc Histogram and Lognormal Distribution

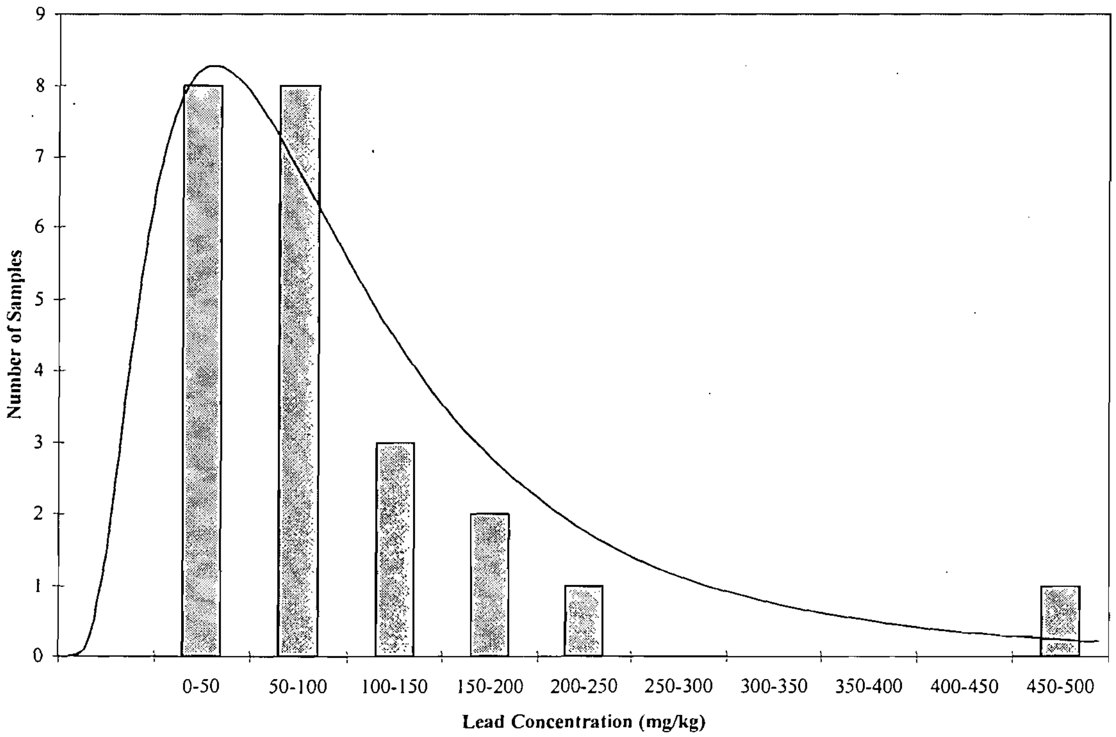

Figure 4-2. Lead Histogram and Lognormal Distribution.

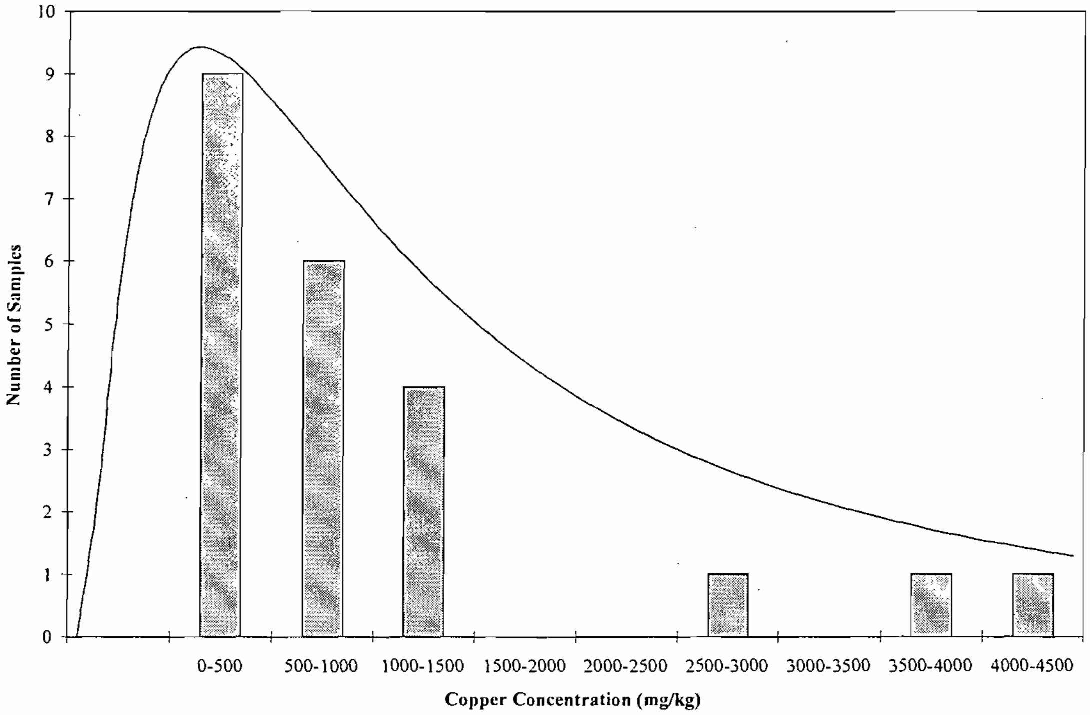

Figure 4-3. Copper Histogram and Lognormal Distribution.

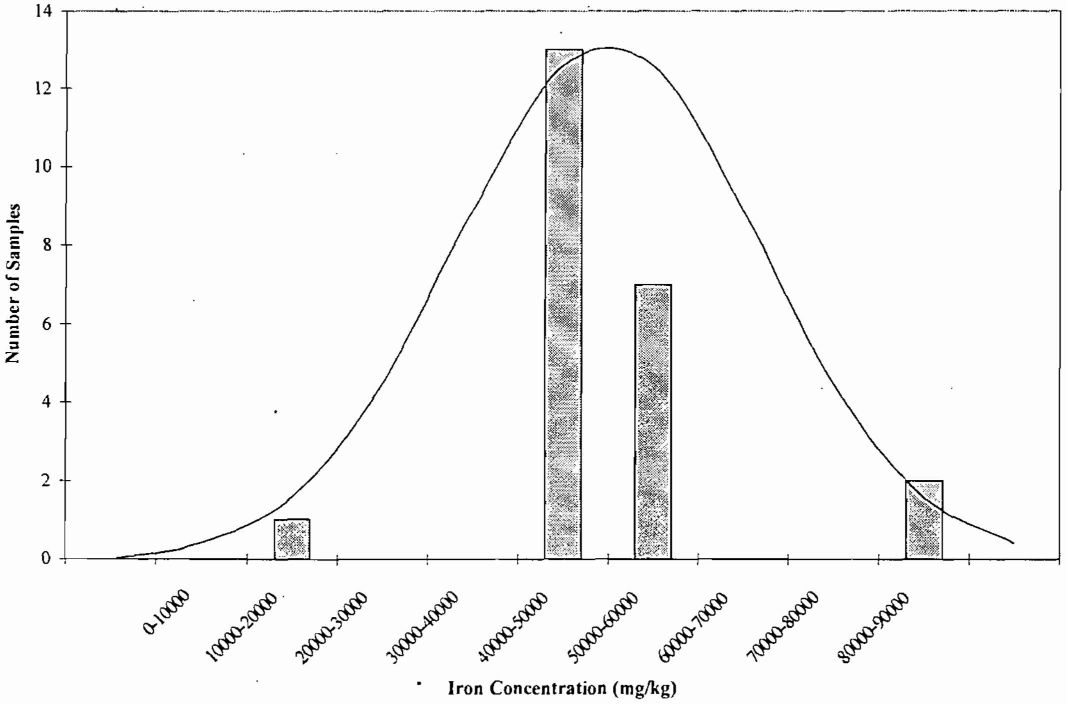

Figure 4-4. Iron Histogram and Normal Distribution.

As discussed earlier, raw coal slag media may contain heavy metals, which contribute to the metal content of this waste stream. Figure 4-5 compares the concentrations of metals in the raw and used media. Note that the ship blast ABM sites used coal slag.

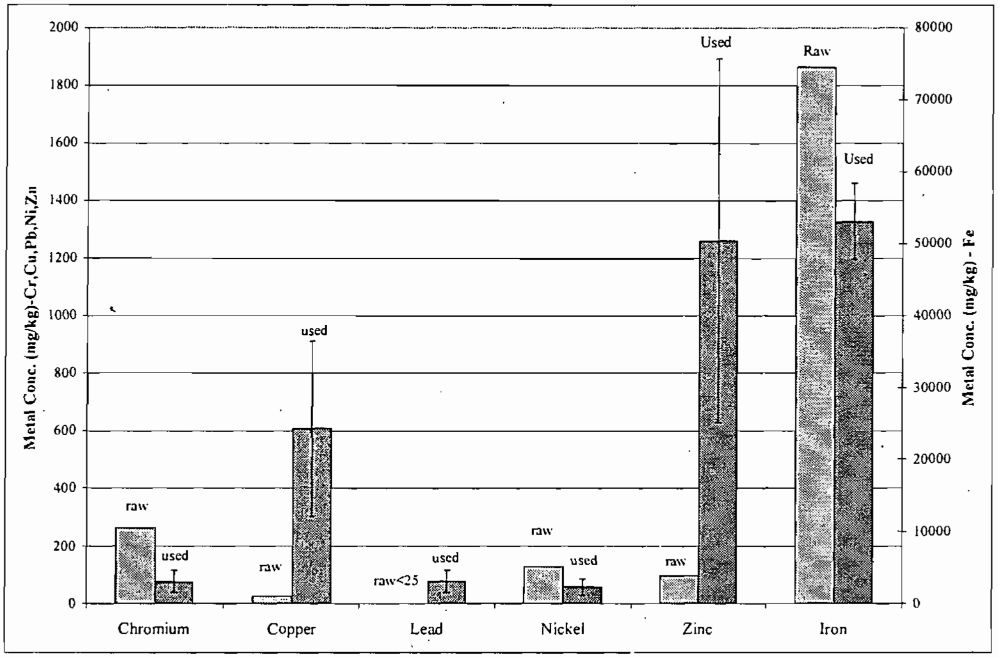

Figure 4-5. Comparison of Raw and Used Media

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 resulted from the blasting process while the chromium, nickel, and iron concentrations resulted from the unused coal slag. The raw media can be extremely variable (Townsend and Carlson, 1998) and users should take care to obtain this media from a reliable supplier.

4.2.1.3 SPLP LEACHING

The SPLP test was performed on all samples collected to assess the potential impact of the waste on groundwater. Table 4-7 lists the leachable metal content of the ABM samples for the SPLP test.

Table 4-7. 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	.010	0.001	0.100	0.200	0.100	0.010	0.100	0.010	0.100
% Detects	0%	74%	0%	95.4%	59%	26%	0%	0%	100%
Minimum	N/A	<.001	N/A	<0.2	<0.1	<.010	N/A	N/A	0.81
Maximum	N/A	0.002	N/A	2.91	0.71	0.041	N/A	N/A	26.97
Geo. Mean[1]	N/A	0.001	N/A	0.72	0.16	0.006	N/A	N/A	5.84
Geo. Std. Dev.	N/A	0.001	N/A	0.46	0.17	0.008	N/A	N/A	1.28
Arith. Mean[1]	N/A	0.001	N/A	1.00	0.25	0.008	N/A	N/A	8.92
Arith. Stnd. Dev.	N/A	.0001	N/A	0.83	0.21	0.008	N/A	N/A	7.67

[1] Average calculated by using ½ the detection limit for undetected samples
[2] Analysis on composite sample from each site

4.2.2 Discussion

4.2.2.1 Hazardous Characteristic

Waste ABM from ship blasting operations 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 showed that the samples collected were not hazardous for the toxicity characteristic.

4.2.2.2 Direct Human Exposure

The total metal concentrations of the ship blasting waste ABM samples were compared to the *Florida Soil Cleanup Target Levels*. As discussed previously, these goals are tools for assessing the contamination or cleanliness of soil or waste. Exceedance of such risk-based standards may control applicable reuse or disposal options.

Sixty-five percent of the samples were above the 0.8 mg/kg residential limit for arsenic, while two samples (9%) were over the industrial limit of 3.7 mg/kg. The residential goal for copper, 105 mg/kg, was exceeded by all but one sample. However, no samples exceeded the industrial goal of 12,000 mg/kg. One hundred percent of the samples exceeded the 23,000 mg/kg residential goal for iron, but none exceeded the industrial goal of 490,000 mg/kg.

These waste materials were located in industrial areas, so the industrial soil cleanup goals would apply assuming necessary institutional controls for maintaining industrial status were placed. As long as there is the possibility of direct exposure (present or future), the soil cleanup goals would apply. The unused media did not exceed the industrial goal for arsenic, nickel, and iron at 2.36 mg/L, 129.5 mg/L, and 74,571 mg/L respectively, but did exceed the residential goals for all three metals. Both the arithmetic and geometric mean for all of the metal data was below the industrial Florida SCTLs. Table 4-8 summarizes the total metal data along with the Florida SCTLs.

Table 4-8. Summary of Total Metal Limits and Comparative Results.

	As	Cd	Cr	Cu	Fe	Pb	Ni	Se	Zn
Res. SCG (mg/kg)	0.8	75	290	105	23,000	500	105	390	23,000
Ind. SCG (mg/kg)	3.7	1300	430	12,000	490,000	920	28,000	9,100	560,000
No. Res. Out of 23	15	0	0	22	23	0	0	0	0
No. Ind. Out of 23	2	0	0	0	0	0	0	0	0

4.2.2.3. Risk to Groundwater

The groundwater guidance concentrations (GWGC) are regulations that can be enforced by FDEP. In this study, four metals exceeded ground water guidance concentrations. One sample exceeded the 0.015 mg/L limit for lead at 0.41 mg/L. Both the arithmetic and geometric mean of the lead data were under the standard. Other samples exceeded the 1.0 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 standards. Half of the samples, as well as both the geometric and arithmetic mean exceeded the 5.0 mg/L limit for zinc.

Table 4-9. Summary of Leaching Limits and Comparative Results.

	As	Cd	Cr	Cu	Fe	Pb	Ni	Se	Zn
GWGC (mg/L)	.05	.005	0.1	1.0	0.3	0.015	0.1	.05	5.0
No. above GWGC (out of 22)	0*	0	0	8	7	1	0	0*	11

*out of 3

4.2.2.4 Correlation of Data

The same sample that was highest for lead was the same sample that exceeded the primary groundwater guidance concentration for lead. This is an indication of the correlation between total metal content and leachable metal content. To investigate leaching characteristics further, a correlation test was performed on the samples exhibiting leaching behavior (i.e. those samples with detectable measurements in both total and leachable concentrations). Figures 4-6 and 4-7 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. Some scatter was present in the correlation, which suggested that the leaching mechanisms of this waste stream were complex and not always predictable. A similar correlation for iron produced a correlation coefficient of less than 0.1. This indicated 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 provide 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%. As seen earlier, much of the iron content was from the media, which may account for the lower leaching rate and the lack of correlation.

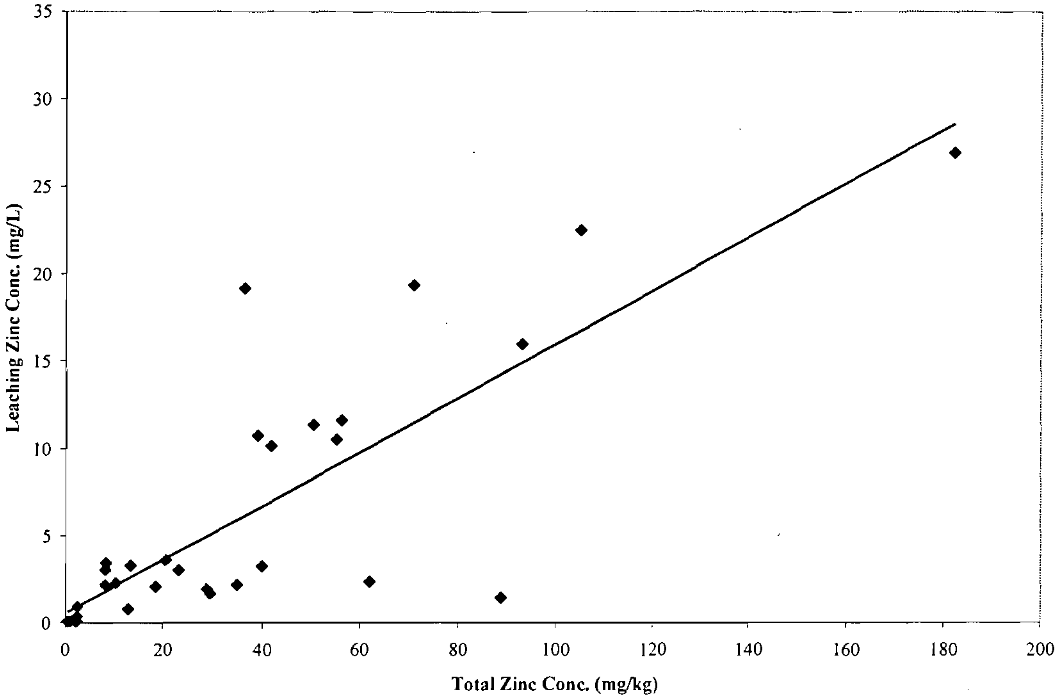

Figure 4-6. Correlation of Leachable and Total Metals for Zinc

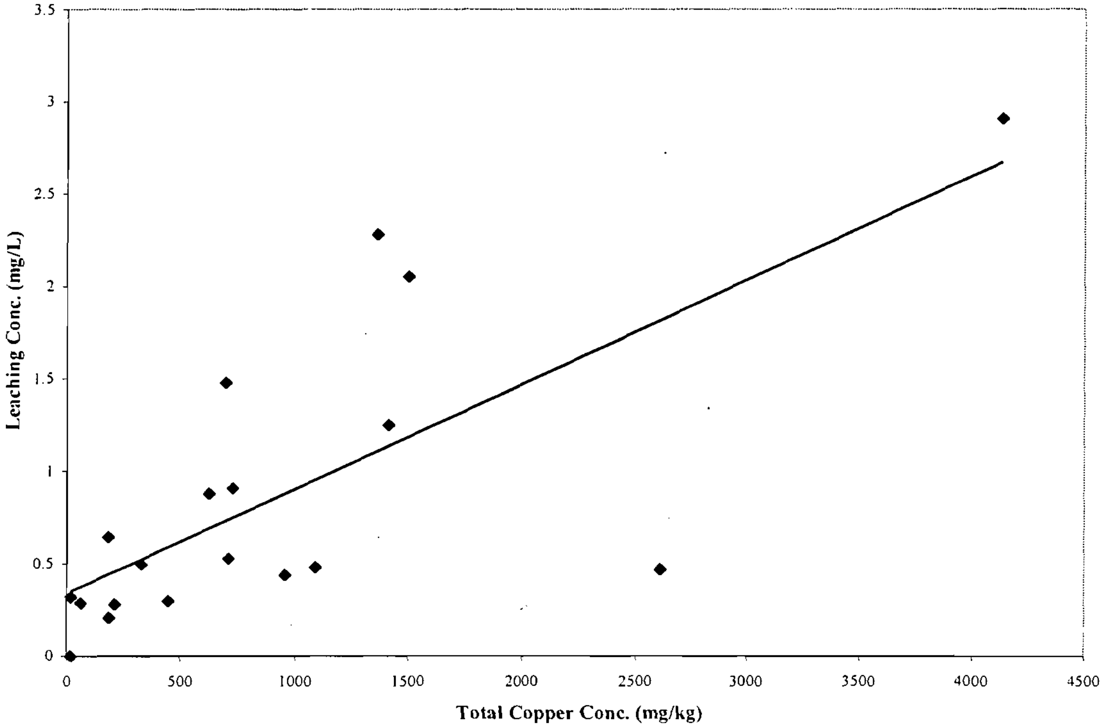

Figure 4-7. Correlation of Leaching and Total Metals for Copper

4.2.2.5 Implication for Management

The concern over the management of the ship maintenance facility 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 content (typically coal slag) and the paint removed with this media creates additional metal concentration. Typically those metals are the ones 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. Table 4-10 is a summary of possible concerns found with the ship maintenance facility waste ABM in this study.

Table 4-10. Potential Concerns with Ship Maintenance Facility Waste ABM

Metal	Direct Exposure Residential	Direct Exposure Industrial	Groundwater-Leaching
Arsenic	Yes	Possibly	No
Cadmium	No	No	No
Chromium	No	No	No
Copper	Yes	No	Possibly
Iron	Yes	No	Possibly
Lead	No	No	Possibly
Nickel	No	No	No
Selenium	No	No	No
Zinc	No	No	Yes

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, so other less costly options may have to be considered. Recycling operations are available for abrasive blasting waste. A promising recycling process was used by two of the maintenance facilities sampled for this study. These facilities recycled the waste produced in a cement kiln. The coal slag contains ingredients used in feedstock for the production of portland cement. Other recycling options include use as aggregate in asphalt or concrete (Townsend and Carlson, 1997).

The results of the research of these three ship maintenance facilities indicated 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.

4.3 RESULTS AND DISCUSSION OF SANDBLASTING CONTRACTORS

4.3.1 Results

The results of the chemical analyses on the sandblasting contractor samples are grouped into three areas: TCLP results, the total metal content, and SPLP metal leachability. These results are compared to both federal and state regulations and guidelines.

4.3.1.1 TCLP Results

The composite samples from each sandblasting contractor facility were tested to see if they were hazardous. Table 4-11 contains the TCLP limits and results from this study.

Table 4-11. 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	BDL	BDL	BDL	BDL
Sndblst Site B	BDL	BDL	.015	BDL	BDL	BDL	BDL	BDL
Sndblst Site C	BDL	BDL	.009	BDL	.020	BDL	BDL	BDL

*Units mg/L, BDL=Below Detection Limit

4.3.1.2 Total Metal Results

Table 4-12 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 (normal, log-normal) of the data can affect the averages and standard deviation of each data set. Figures 4-8 through 4-11 present the histograms including a line representing a lognormal distribution for zinc, lead, chromium, and nickel.

Table 4-12. 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.

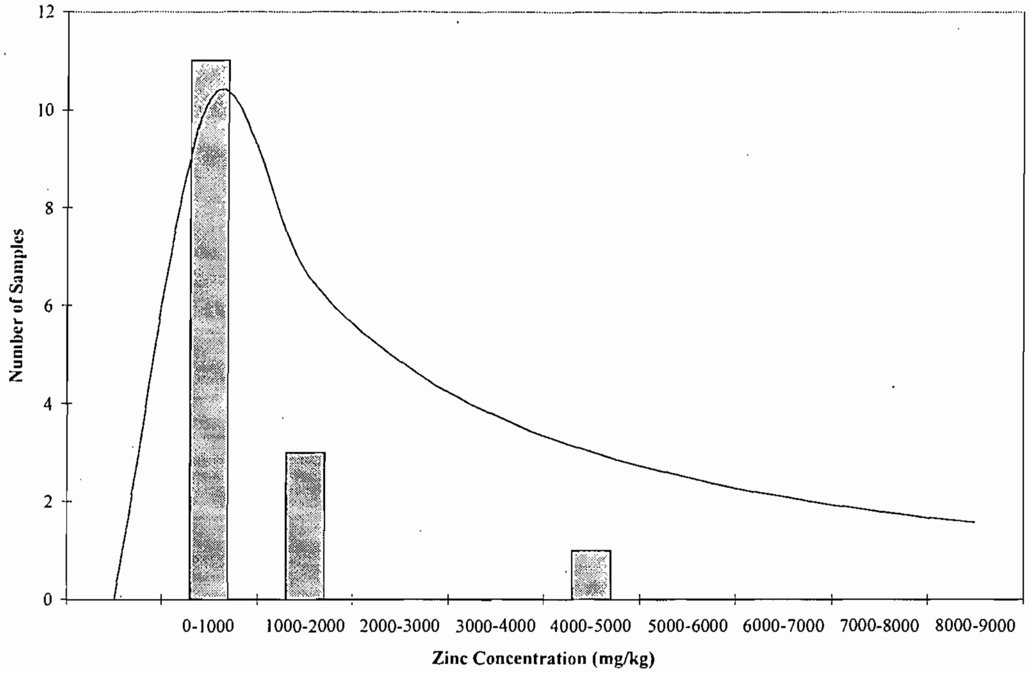

Figure 4-8. Zinc Histogram and Lognormal Distribution.

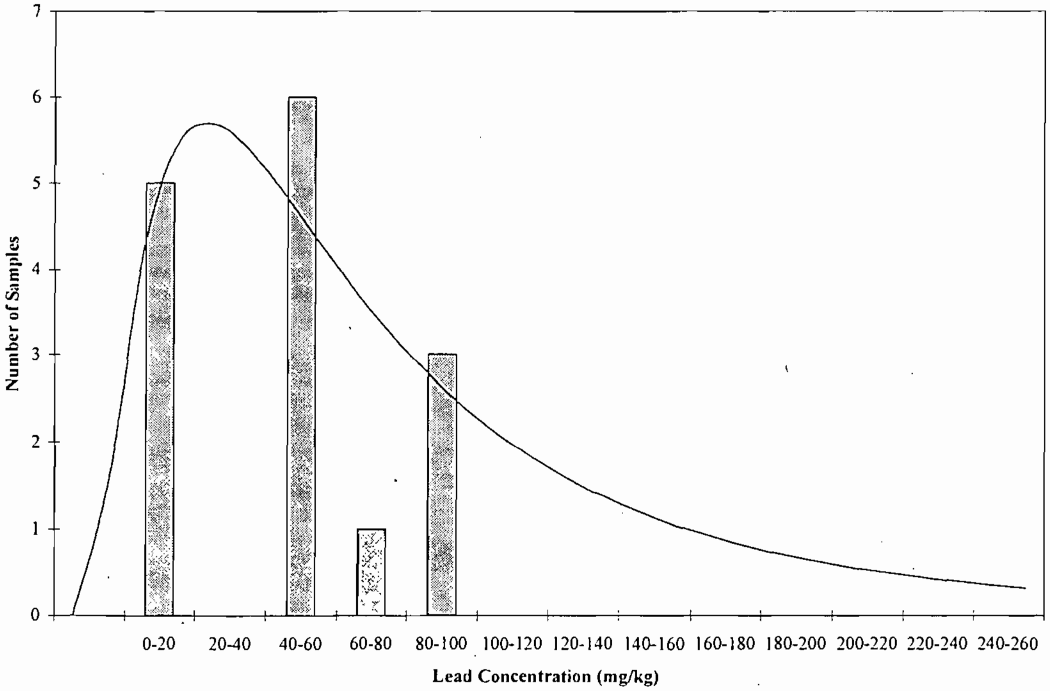

Figure 4-9. Lead Histogram and Lognormal Distribution.

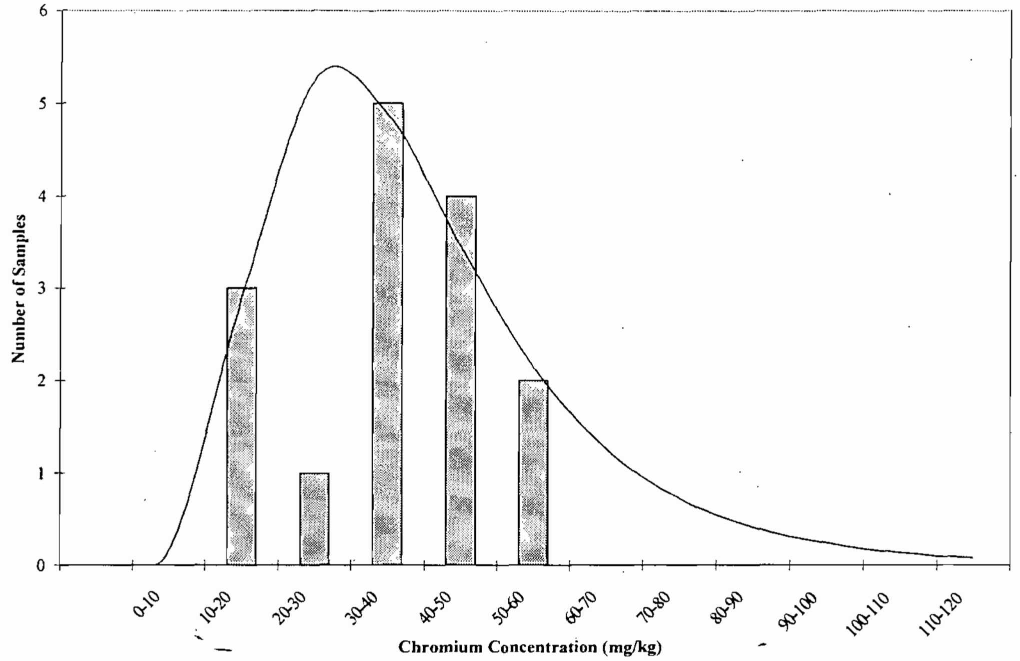

Figure 4-10. Chromium Histogram and Lognormal Distribution.

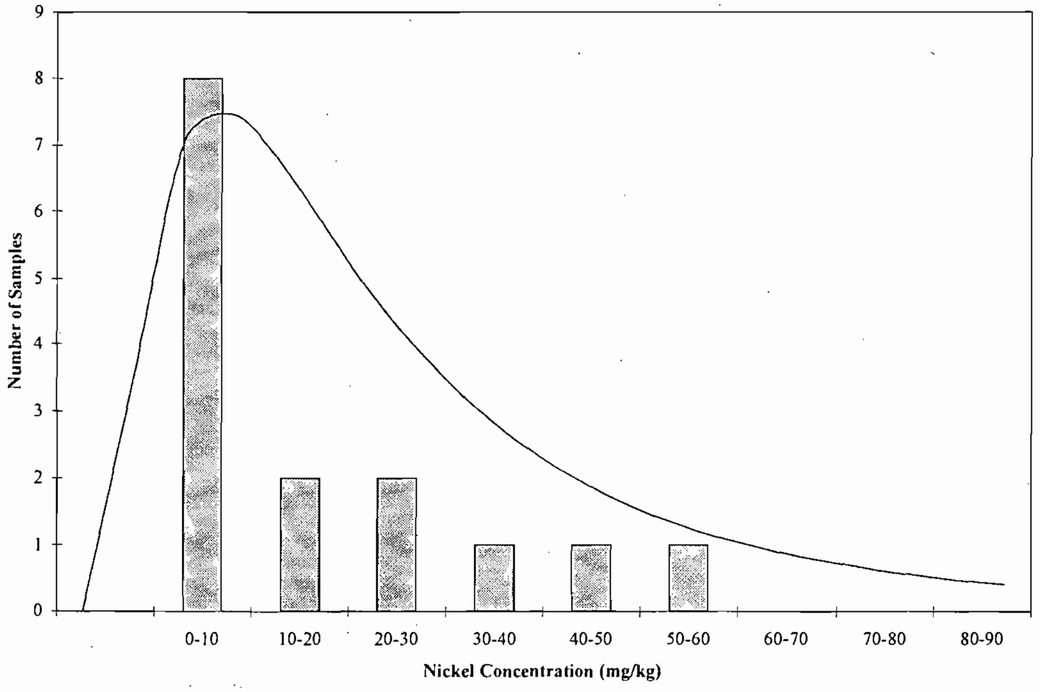

Figure 4-11. Nickel Histogram and Lognormal Distribution.

Table A-2. Data for Total Metal-Flame

TOTAL	METALS	Sample wt.	Lead	Copper	Chromium	Zinc	Cadmium	Nickel	Iron
SAMPLE ID		g	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg
MSBLANK	Blank Spike (mg/L)	-	4.5	4.7	5.2	4.6	2.3	5.0	2.7
SBA1		2.20	78.6	3579.5	50.9	2738.6	<2.5	72.3	50454.5
SBA1MS	Matrix Spike	2.11	273.0	-	226.5	-	105.7	294.8	
SBA1MSD	Matrix Spike - Dup	2.27	259.0	-	196.5	-	101.3	261.2	
SBA2		2.40	39.6	183.3	52.1	2102.1	<2.5	62.1	46166.7
SBA2D	Field Dup	2.04	40.7	211.8	48.5	1781.9	<2.5	54.4	49166.7
SBA3		2.12	44.8	448.6	125.0	3344.3	<2.5	71.7	51509.4
SBA4		2.23	25.6	326.9	73.1	373.9	<2.5	41.7	44529.1
SBA4D	Field Dup	2.01	26.4	62.2	93.0	119.7	<2.5	46.8	51865.7
SBA5		2.08	40.9	1086.5	99.5	1870.2	<2.5	55.3	49326.9
SBA6		2.40	183.8	1500.0	104.2	2297.9	<2.5	100.8	109479.2
SBB1		2.02	67.3	2607.4	93.6	3071.8	<2.5	53.0	44594.1
SBB2		2.37	216.5	192.0	126.2	215.7	<2.5	55.7	42995.8
SBB2D	Method Dup	2.04	194.1	307.8	135.3	306.9	<2.5	63.7	49313.7
SBB3		2.38	102.5	697.5	111.3	558.8	<2.5	57.6	46512.6
SBB4		2.10	140.0	709.5	103.8	390.0	<2.5	56.2	49428.6
SBB5		2.36	55.1	4131.4	114.0	4447.0	<2.5	58.5	42881.4
SBB6		2.20	105.9	954.5	92.3	4231.8	<2.5	64.5	45313.6
SBC1		2.06	78.2	728.2	45.6	997.6	<2.5	51.9	48291.3
SBC2		2.02	60.9	1361.4	47.0	2787.1	<2.5	61.9	56980.2
SBC3		1.94	446.4	184.0	95.9	2054.1	<2.5	50.5	54948.5
SBC4		2.09	77.5	1411.5	54.5	1105.3	<2.5	48.3	52392.3
SBC5		2.01	93.5	626.9	69.2	916.7	<2.5	68.2	88432.8
SBC6		2.19	87.7	474.0	39.7	588.1	<2.5	42.9	45547.9
SBC7		2.05	38.0	365.9	42.4	8885.4	<2.5	67.8	53073.2
SBC8		2.00	40.5	516.5	47.0	2085.0	<2.5	59.0	89712.5
GCA1		2.05	<25	<25	44.9	4328.0	<2.5	9.3	2801.0
GCA2		2.13	<25	<25	31.0	484.7	<2.5	12.7	1379.3
GCA3		2.07	81.2	<25	33.3	1678.7	<2.5	7.7	1527.5
GCA4		2.46	<25	<25	12.6	329.1	<2.5	7.3	882.1
GCA5		2.07	<25	<25	26.1	1386.5	<2.5	12.6	903.9
GCA6		2.28	<25	<25	17.1	1290.6	<2.5	5.7	826.8
GCB1		2.09	99.5	<25	45.5	102.8	<2.5	4.8	875.1
GCB2		2.34	71.8	<25	37.2	99.6	<2.5	9.4	939.3
GCB3		2.01	44.3	<25	17.4	100.1	<2.5	7.0	1595.0
GCB4		2.51	54.6	<25	41.0	92.1	<2.5	7.6	1072.9
BLANK		-	BDL	BDL	BDL	BDL	BDL	BDL	BDL
GCC1		2.13	58.7	<25	32.9	24.3	<2.5	22.1	1626.8
GCC2		1.60	43.8	<25	53.8	26.1	<2.5	53.1	1813.8
GCC3		1.98	82.3	<25	59.1	30.9	<2.5	49.5	1744.9
GCC4		1.75	57.7	<25	38.9	29.6	<2.5	27.4	1474.9
GCC5		1.56	53.2	<25	43.6	65.4	<2.5	35.9	1233.3

APPENDIX A

QA/QC Data

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limits may also occasionally be exceeded, storage on an impervious surface, like concrete is recommended. Waste ABM may be disposed of in a lined landfill or recycled in a manner which will not produce leachate when the waste exceeds groundwater guidance concentrations. An excellent recycling option for the coals slag used media is at a cement kiln. The media contains minerals needed as feedstock in the cement-making process. Other recycling options include as aggregate in concrete or asphalt.

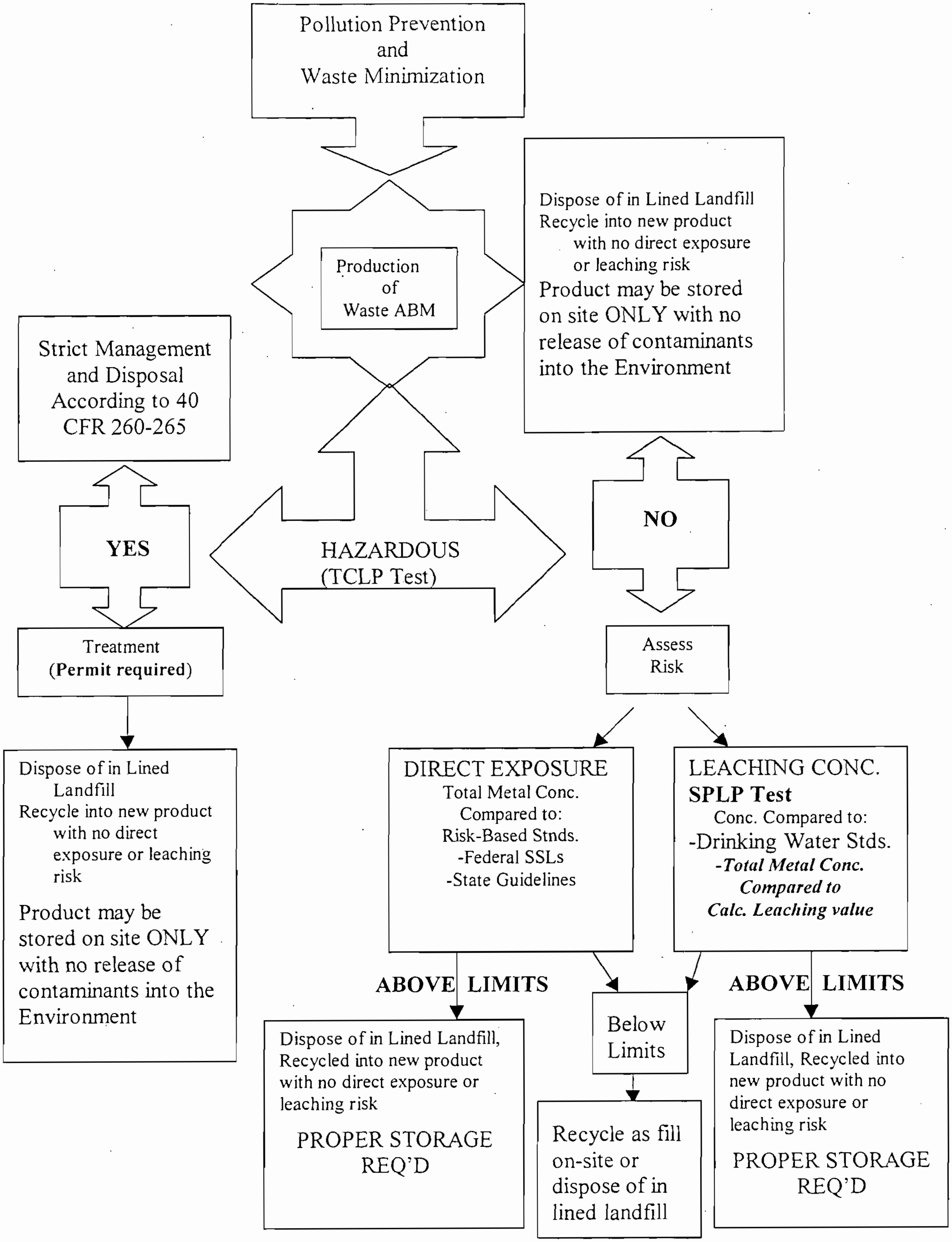

Figure 5-1. Overview of Management Options

Table 4-24. 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%

23.5% = 4.25

Table 4-25. 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%

6.28% = 15.9

Table 4-26. 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%

68.1 = 1.46

4.4.2.3 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 occurring inside 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 1997). 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 providing some degree of dilution of the leachate as might occur in the environment (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 assess the impact of this waste stream on the natural environment.

The concentrations of some of the heavy metals exceeded groundwater guidance concentrations in lysimeters. This included some cases where the GWGCs were not exceeded in the SPLP tests. A complete examination of the lysimeter data and their relationship with the batch SPLP data was beyond the scope of this report. For additional information and discussion, see the Master of Engineering thesis by Carlson (1998). Additional analyses and examination will be performed as part of technical journal articles that will be drafted and submitted in the future.

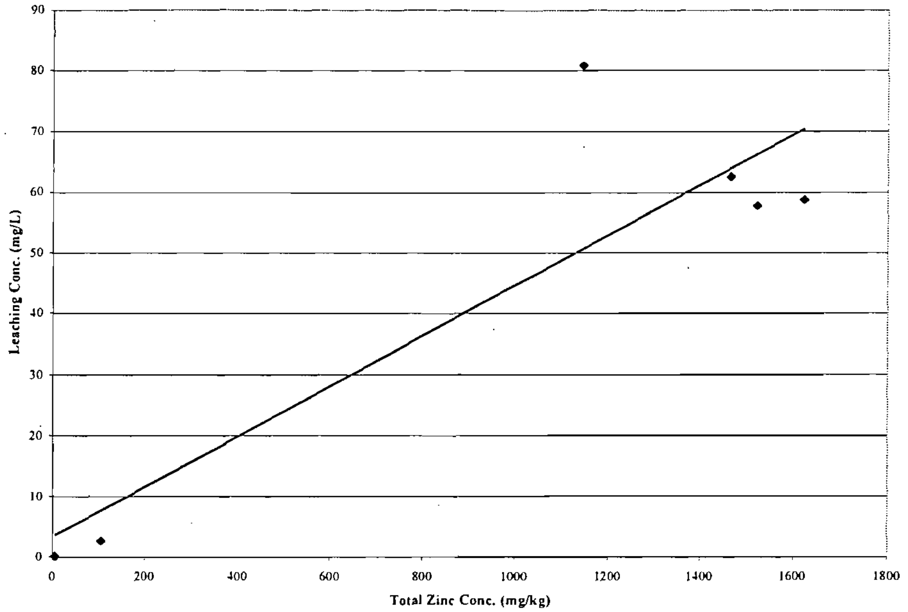

Figure 4-20. Zinc TCLP and Total Metal Correlation.

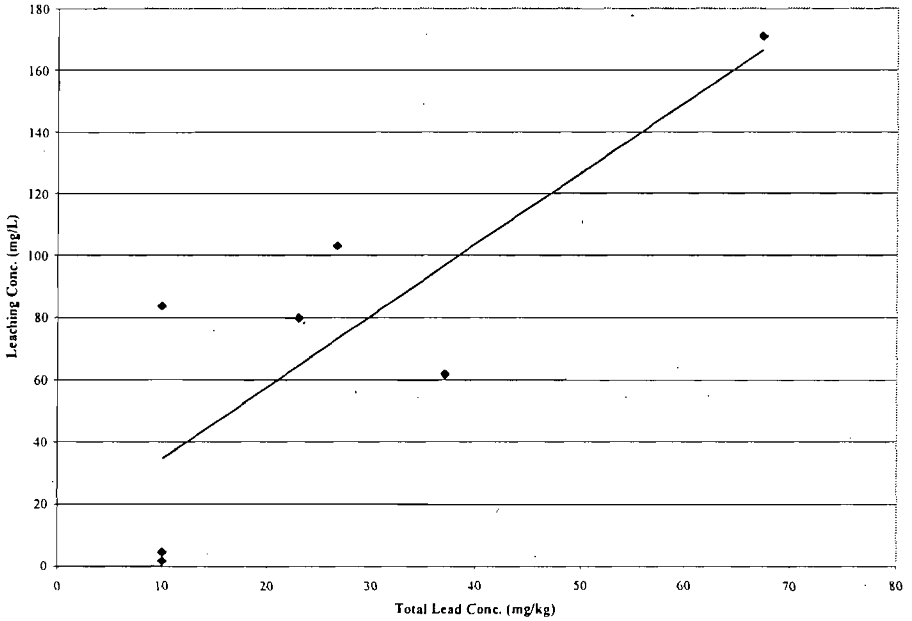

Figure 4-21. Copper TCLP and Total Metal Correlation.

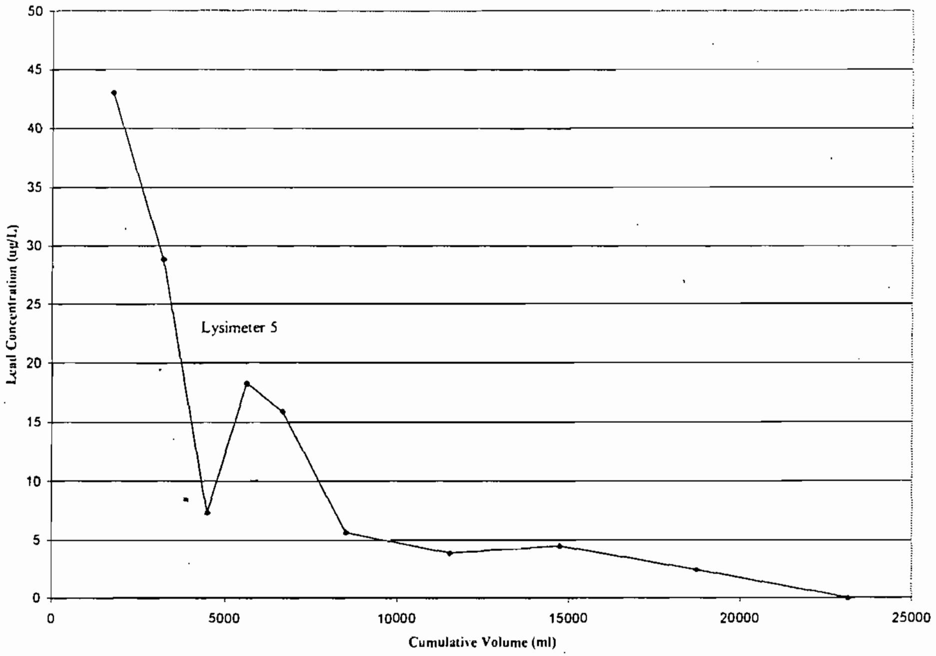

Figure 4-18. Lead Leaching from Lysimeter 5.

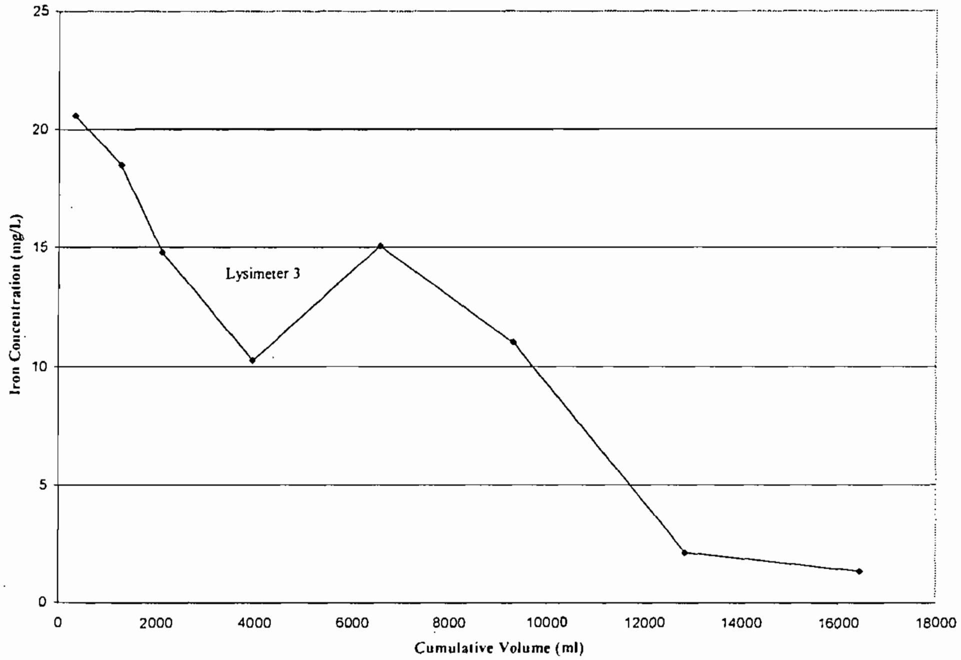

Figure 4-19. Iron Leaching from Lysimeter 3.

Table 4-23. Heavy Metals found in Lysimeter Leachate (mg/L).

	L1	L2	L3	L4	L5	L6	L7	L8
No. Detected	0	0	2	0	7	0	0	0
Max Cadmium	N/A	N/A	.011	N/A	.004	N/A	N/A	N/A
Min Cadmium	N/A	N/A	<.001	N/A	<.001	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 4-16 through 4-19 present the leaching curves for these metals from their respective lysimeters.

Conductivity and TDS are related. The more total dissolved solids, the more ions available to produce conductance. Table 4-20 shows some relationship between them, and this was further investigated. The ions contribute to the TDS and conductivity and Table 4-21 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 4-22 is a "solids balance" for the total amount of ions leached and the total TDS leached for each lysimeter. The sums matched up relatively well in most cases, with all ion sums slightly lower. Differences may be explained by organic matter (Lys 3) and other non-detected ions. Figure 4-15 presents the leaching curve for conductivity. TDS and the inorganic ions followed this same trend.

Table 4-21. 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 4-20. General Water Quality 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 $CaCO_3$

media (Lysimeter 6) compared to the used media, indicated that some of the metals (As, Cr, Ni) were inherent to the media and other metals (Cu, Zn, Pb) came from the blasting residuals. The sandblasting contractor samples (Lysimeters 3 and 5) were similar, except lysimeter 3 had more iron and lysimeter 5 had more zinc. The unused silica sand media contained no metals above detection limits except for a small amount of mercury and some iron.

Table 4-17. 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

The leaching concentrations of the samples varied, indicating that complex leaching mechanisms are involved in the batch processes. Lysimeters 1 and 2 duplicated 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.

Table 4-18. 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 4-14. **Summary Total Metal Limits and Comparative Results.**

	As	Cd	Cr	Cu	Fe	Pb	Ni	Se	Zn
Res. SCG (mg/kg)	0.8	75	290	105	23,000	500	105	390	23,000
Ind. SCG (mg/kg)	3.7	1300	430	12,000	490,000	920	28,000	9,100	560,000
No. Res.	0	0	0	0	0	0	0	0	0
No. Ind.	0	0	0	0	0	0	0	0	0

4.3.2.3 Risk to Groundwater

The drinking water standards adopted 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 appeared normally distributed and therefore the arithmetic mean would likely be used.

Table 4-15. Summary of Leaching Limits and Comparative Results.

	As	Cd	Cr	Cu	Fe	Pb	Ni	Se	Zn
GWGC (mg/L)	.05	.005	0.1	1.0	0.3	0.015	0.1	.05	5.0
No. above GWGC (out of 15)	0*	1	0	0	7	0	0	0*	0

*Out of 3

4.3.2.4 Correlation of Data

A correlation of total metal amounts and leachability was performed on the individual samples above the detection limits. There was little correlation observed 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%.

4.3.2.5 Implication for Management

Sandblasting contractor waste was non-hazardous for the sites characterized in this study. The sites sampled for this research blasted various equipments from scaffolding to heavy machinery. The concentration of heavy metals in the sandblast grit did not pose direct threat to human health when compared to state and risk-based standards. This waste could be land applied if it would not potentially contaminate the ground water at the site. Table 4-16 summarizes the main concerns with sandblasting contractor waste ABM.

Table A-2 continued.

TOTAL	METALS	Sample wt.	Lead	Copper	Chromium	Zinc	Cadmium	Nickel	Iron
LYS1		2.10	26.7	1909.5	98.6	1463.8	<2.5	59.0	80809.5
LYS2		2.00	23.0	1125.0	114.5	1522.5	<2.5	68.5	72500.0
LYS3		2.00	37.0	<25	49.0	104.5	<2.5	12.0	3163.5
LYS4		2.20	67.3	3336.4	133.6	1622.7	<2.5	56.4	62681.8
LYS5		2.10	<25	<25	48.1	1145.2	<2.5	12.4	2080.5
BB Comp		2.10	<25	28.1	265.2	98.6	<2.5	129.5	74571.4
SS Comp		1.90	<25	<25	<5	<5	<2.5	<5	168.9
SBB2MS		1.884		812.1		810.0			3220.0
SBB2MSD		1.9061		802.7		797.4			3339.7

Table A-3. Data for Total Metal-Furnace

SAMPLE ID	Sample Wt. (g)	Arsenic (mg/kg)	Selenium (mg/kg)	SAMPLE ID	Sample Wt. (g)	Arsenic (mg/kg)	Selenium (mg/kg)
MSBLANK	mg/L	0.128	0.075	GCA1	2.02	<.05	<0.5
SBA1	2.00	0.25	<0.5	GCA2	2.03	<.05	<0.5
SBA2	2.02	0.30	<0.5	GCA3	2.01	<.05	<0.5
SBA2D	2.00	0.35	<0.5	GCA4	1.99	<.05	<0.5
SBA3	2.04	4.64	<0.5	GCA5	2.00	<.05	<0.5
SBA4	2.04	0.95	<0.5	GCA6	2.01	0.07	<0.5
A4D	2.04	2.24	<0.5	GCB1	2.00	<.05	<0.5
SBA5	2.04	3.23	<0.5	GCB2	2.04	0.08	<0.5
SBA6	2.05	1.97	<0.5	GCB3	2.01	0.08	<0.5
SBB1	2.03	0.09	<0.5	GCB4	2.00	0.06	<0.5
SBB2	2.01	3.27	<0.5	BLANK		<.05	<0.5
SBB2D	2.00	2.03	<0.5	GCC1	2.00	0.17	<0.5
SBB3	2.00	2.18	<0.5	GCC2	2.01	<.05	<0.5
SBB4	2.00	1.96	<0.5	GCC3	2.01	0.14	<0.5
SBB5	2.03	3.88	<0.5	GCC4	2.00	0.07	<0.5
SBB6	2.00	2.36	<0.5	GCC5	2.00	0.10	<0.5
SBC1	2.03	2.15	<0.5	LYS1	2.02	1.99	<0.5
SBC2	2.03	3.27	<0.5	LYS2	2.01	2.38	<0.5
SBC3	2.01	2.97	<0.5	LYS3	2.01	0.10	<0.5
SBC4	2.01	0.25	<0.5	LYS4	2.04	1.92	<0.5
SBC5	2.03	2.41	<0.5	LYS5	2.04	<.05	<0.5
SBC6	2.01	0.31	<0.5	LYS6	2.00	2.36	<0.5
SBC7	2.02	0.46	<0.5	LYS7	2.00	<.05	<0.5
SBC8	2.00	0.27	<0.5	LYS6MS	2.00	5.25	4.23
				LYS6MSD	2.00	4.93	3.92

Table A-4. Mercury Total Metal and Leaching Data

Sample ID	Sample Wt (g)	Tot Met mg/kg	TCLP (mg/L)	SPLP (mg/L)
LYS1	2.1	0.0041	<.0001	<.0001
LYS2	2.0	0.0043	<.0001	<.0001
LYS3	2.2	0.0019	<.0001	<.0001
LYS4	2.0	0.0011	<.0001	<.0001
LYS5	2.0	0.0020	<.0001	<.0001
LYS6	2.0	0.0027	<.0001	<.0001
LYS7	2.0	0.0012	<.0001	<.0001
MS1	2.09	0.433	<.0001	<.0001
MS2	2.05	0.417	<.0083	<.0066

Table A-5. SPLP Data

SAMPLE ID		Lead	Copper	Chromium	Zinc	Nickel	Cadmium	Iron	Arsenic	Selenium
		mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
MSBLANK	Matrix Spike	1.1	1.36	1.03	1.014	0.85	0.8	1.21	-	-
SBB3		0.01	1.48	<0.1	3.319	<0.1	<.001	<0.1	-	-
SBB3MS	Matrix Spike	1.2	2.73	1.05	4.105	0.9	0.85	1.12	-	-
SBB3D		<0.01	1.56	<0.1	3.318	<0.1	0.001	<0.1	-	-
SBB3DMS	Matrix Spike - Dup	1.325	2.7	1.04	3.969	0.88	0.75	1.33	-	-
GCA5		<0.01	<0.2	<0.1	2.001	<0.1	<.001	1.14	-	-
GCA5MS	Matrix Spike	1.15	1.06	1.07	3.008	0.84	0.8	2.02	-	-
GCA5D		<0.01	<0.2	<0.1	2.566	<0.1	<.001	0.36	-	-
GCA5DMS	Matrix Spike - Dup	1.1	1.05	1.08	3.282	0.79	0.85	1.51	-	-
SBA1		<.010	2.66	<0.1	8.19	<0.1	0.001	<0.1	-	-
SBA2		0.01	0.65	<0.1	11.4	<0.1	0.001	0.66	-	-
SBA2D	Field Dup	<.010	0.28	<0.1	19.2	<0.1	0.001	0.2	-	-
SBA3		0.014	0.3	<0.1	19.38	<0.1	0.002	0.71	-	-
SBA4		<.010	0.5	<0.1	3.476	<0.1	0.001	0.18	-	-
SBA4D	Field Dup	<.010	0.29	<0.1	0.939	<0.1	<.001	0.35	-	-
SBA5		<.010	0.48	<0.1	10.78	<0.1	0.001	0.23	-	-
SBA6		<.010	2.05	<0.1	10.54	<0.1	0.001	<0.1	-	-
SBB1		<.010	0.47	<0.1	2.399	<0.1	0.001	<0.1	-	-
SBB4		<.010	0.53	<0.1	3.071	<0.1	<.001	0.47	-	-
SBB5		<.010	2.91	<0.1	22.54	<0.1	0.002	<0.1	-	-
SBB6		<.010	0.44	<0.1	16.02	<0.1	0.001	<0.1	-	-
SBC1		<.010	0.91	<0.1	3.634	<0.1	0.001	0.43	-	-
SBC2		<.010	2.28	<0.1	11.64	<0.1	<.001	0.1	-	-
SBC3		0.041	0.21	<0.1	3.296	<0.1	0.001	<0.1	-	-

Table A-5 continued

SAMPLE ID		Lead	Copper	Chromium	Zinc	Nickel	Cadmium	Iron	Arsenic	Selenium
SBC4		<.010	1.25	<0.1	3.034	<0.1	0.002	0.47	-	-
SBC5		0.011	0.88	<0.1	2.111	<0.1	0.001	0.27	-	-
SBC6		0.011	<0.2	<0.1	0.807	<0.1	<.001	0.32	-	-
SBC7		<.010	0.32	<0.1	26.975	<0.1	0.002	0.24	-	-
SBC8		<.010	1.37	<0.1	10.2	<0.1	0.001	<0.1	-	-
GCA1		<.010	<0.2	<0.1	1.475	<0.1	<.001	0.3	-	-
GCA2		<.010	<0.2	<0.1	2.297	<0.1	<.001	0.45	-	-
GCA3		<.010	<0.2	<0.1	2.191	<0.1	<.001	<0.1	-	-
GCA4		<.010	<0.2	<0.1	2.22	<0.1	<.001	0.23	-	-
GCA6		<.010	<0.2	<0.1	1.709	<0.1	<.001	0.18	-	-
GCB1		<.010	<0.2	<0.1	<0.1	<0.1	0.001	0.3	-	-
GCB2		<.010	<0.2	<0.1	<0.1	<0.1	<.001	0.59	-	-
GCB3		<.010	<0.2	<0.1	<0.1	<0.1	<.001	0.35	-	-
GCB4		<.010	<0.2	<0.1	0.385	<0.1	0.009	0.58	-	-
BLANK		<.010	<0.5	<0.1	<0.1	<0.1	<.001	0.13	-	-
BLANK		<.010	<0.5	<0.1	<0.1	<0.1	<.001	<0.1	-	-
GCC1		<0.010	<0.5	<0.1	<0.10	<0.1	<.001	0.51	-	-
GCC2		<0.010	<0.5	<0.1	<0.10	<0.1	<.001	0.14	-	-
GCC3		<0.010	<0.5	<0.1	<0.10	<0.1	<.001	0.34	-	-
GCC4		<0.010	<0.5	<0.1	<0.10	<0.1	<.001	0.5	-	-
GCC5		<0.010	<0.5	<0.1	<0.10	<0.1	<.001	0.24	-	-
LYS1		<0.010	<0.5	<0.1	1.68	<0.1	<.001	0.42	<.010	<.010
LYS2		<0.010	<0.5	<0.1	2.63	<0.1	<.001	0.68	<.010	<.010
LYS3		<0.010	<0.5	<0.1	0.25	<0.1	<.001	0.7	<.010	<.010
LYS4		<0.010	<0.5	<0.1	1.07	<0.1	<.001	0.5	<.010	<.010
LYS5		<0.010	<0.5	<0.1	1.81	<0.1	<.001	0.41	<.010	<.010
BB Comp		<0.010	<0.5	<0.1	<0.10	<0.1	<.001	0.61	<.010	<.010
SS Comp		<0.010	<0.5	<0.1	<0.10	<0.1	<.001	0.44	<.010	<.010
GCC		<0.010	<0.5	<0.1	<0.10	<0.1	<.001	0.85	<.010	<.010
SBC		<0.010	<0.5	0.11	1.35	<0.1	<.001	0.97	<.010	<.010

Table A-6. TCLP Data

	Copper	**Zinc**	**Chromium**	**Barium**	**Nickel**	**Lead**	**Cadmium**	**Silver**	**Iron**	**Arsenic**	**Selenium**
Sample ID	mg/L	mg/L	mg/L	Mg/L	mg/L	ug/L	ug/L	mg/L	mg/L	mg/L	mg/L
lys 1	17.5	62.55	<0.1	<10	<0.1	103	3.716	<0.1	5.58	<.010	<.010
lys 2	20	57.89	<0.1	<10	<0.1	79.85	3.712	<0.1	1.54	<.010	<.010
lys 3	<0.50	2.64	<0.1	<10	<0.1	61.88	15.28	<0.1	4.97	<.010	<.010
lys 4	27.9	58.84	<0.1	<10	<0.1	171.1	3.668	<0.1	1.47	<.010	<.010
lys 5	<0.50	32.38	<0.1	<10	<0.1	83.72	1.467	<0.1	<0.1	<.010	<.010
lys 6	<0.50	0.1	<0.1	<10	0.28	<.010	<.001	<0.1	21.1	<.010	<.010
lys 7	<0.50	<0.1	<0.1	<10	<0.1	<.010	<.001	<0.1	<0.1	<.010	<.010
GCC	<0.50	0.548	0.13	<10	<0.1	20.37	9.5	<0.1	0.24	<.010	<.010
SBC	11.7	76.91	<0.1	<10	<0.1	154.9	4.63	<0.1	2.85	<.010	<.010

APPENDIX B

Lysimeter Data

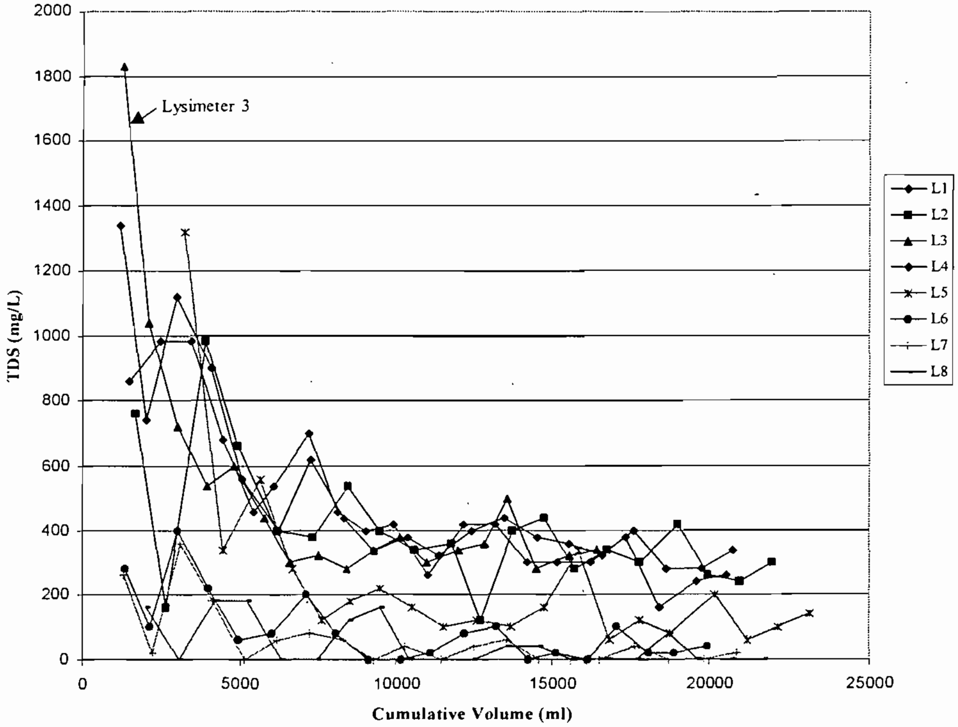

Figure B-1. TDS Leaching Curves .

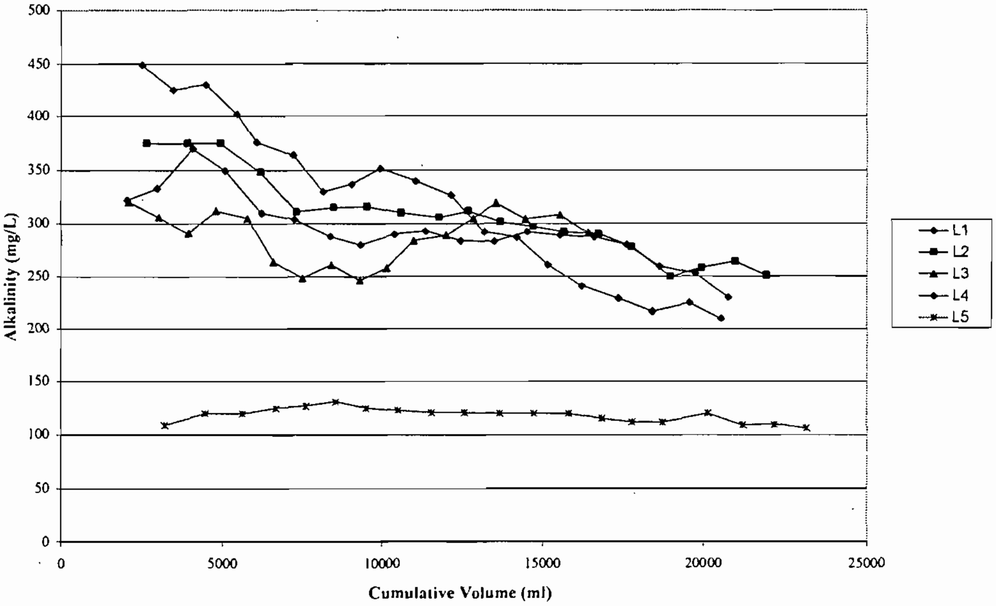

Figure B-2. Alkalinity Leaching Curves.

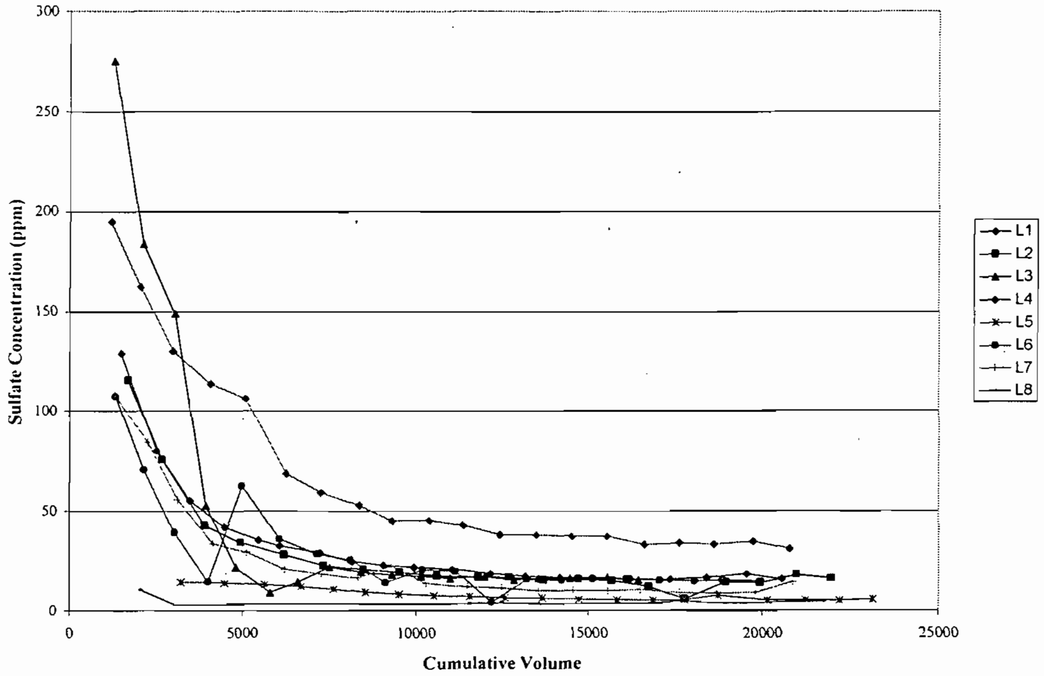

Figure B-3. Sulfate Leaching Curves

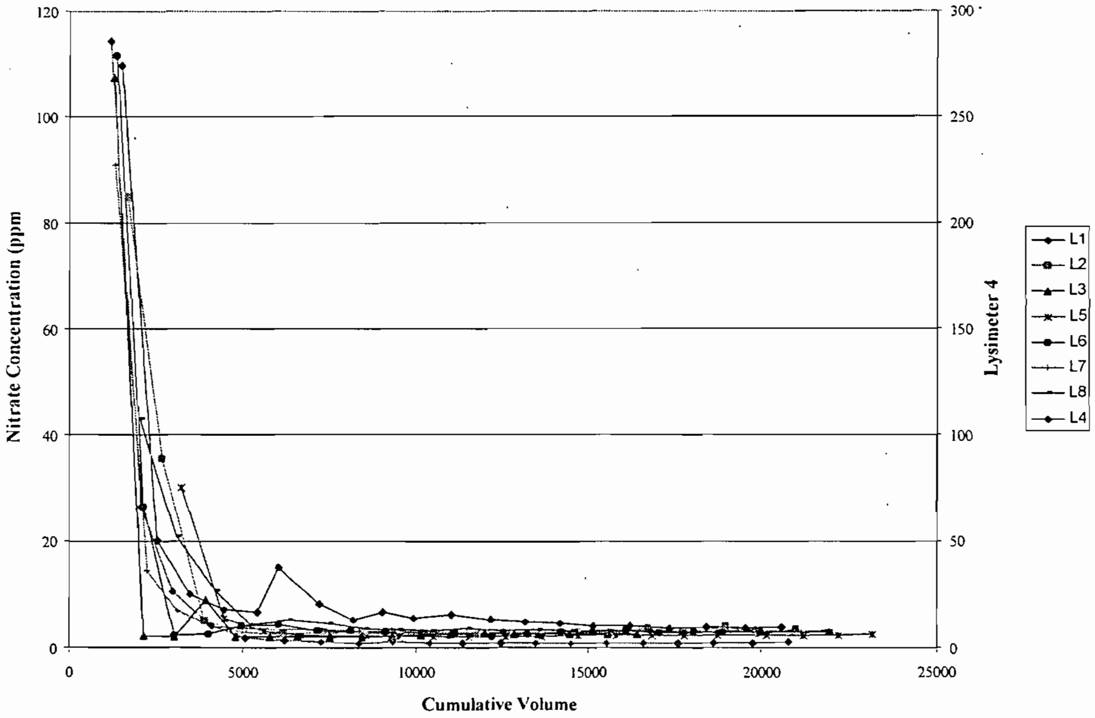

Figure B-4. Nitrate Leaching Curves

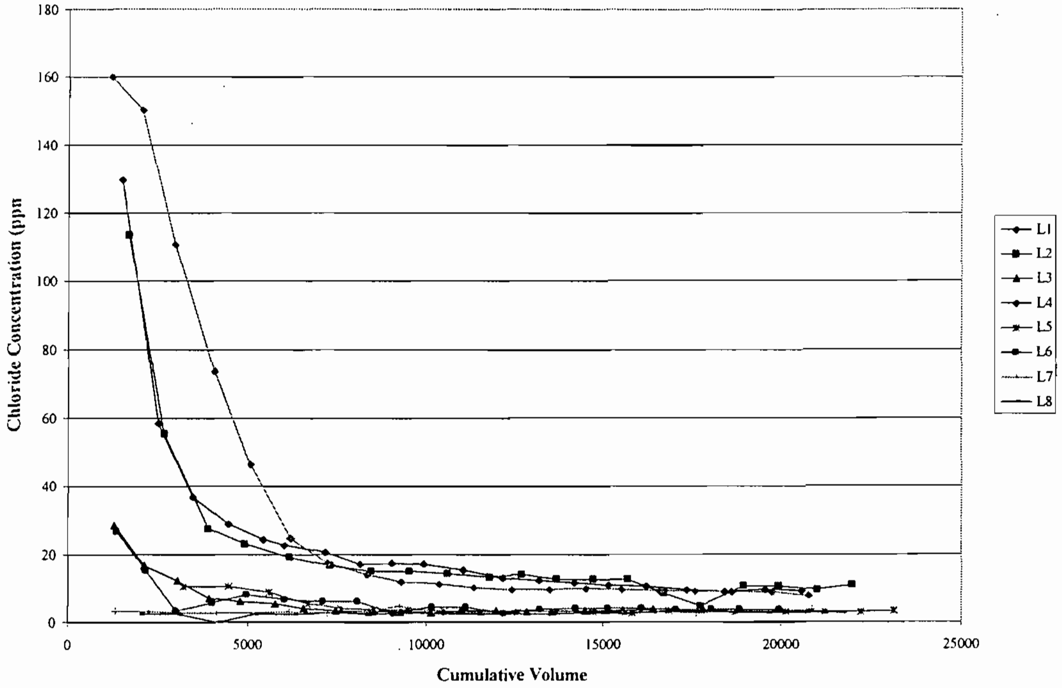

Figure B-5. Chloride Leaching Curves.

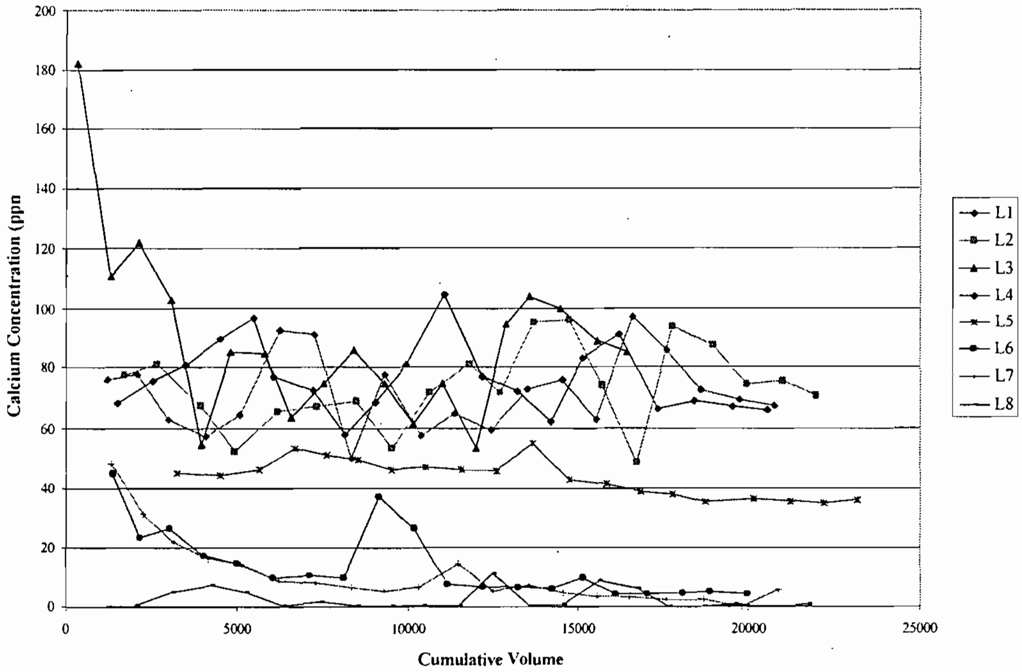

Figure B-6. Calcium Leaching Curves.

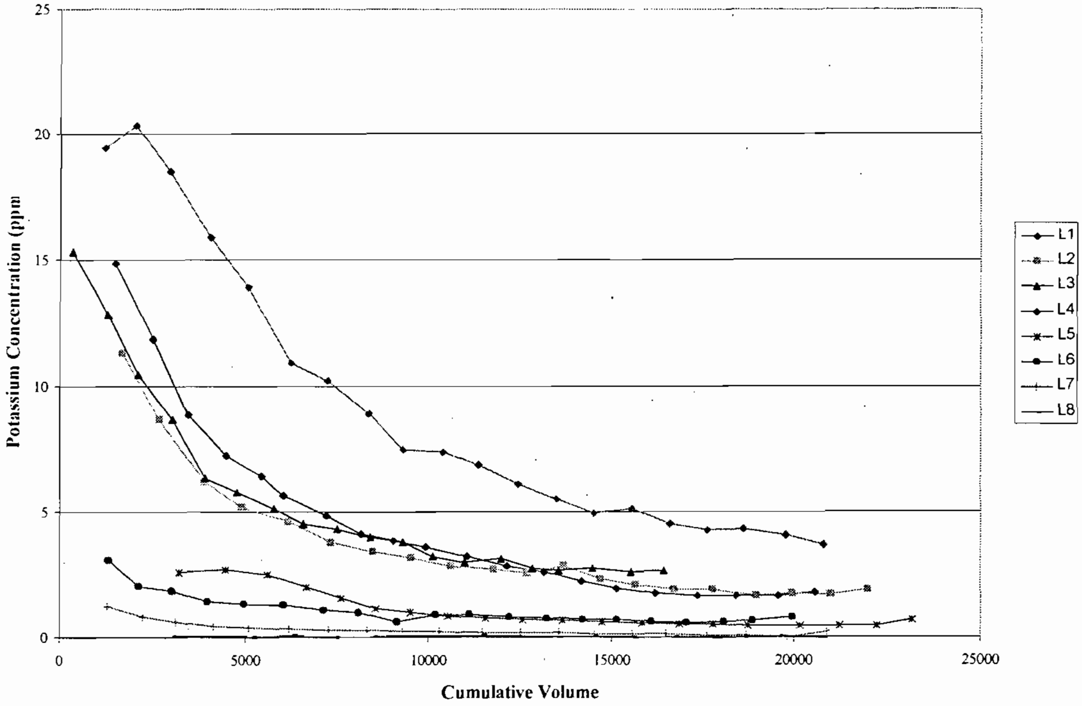

Figure B-7. Potassium Leaching Curves.

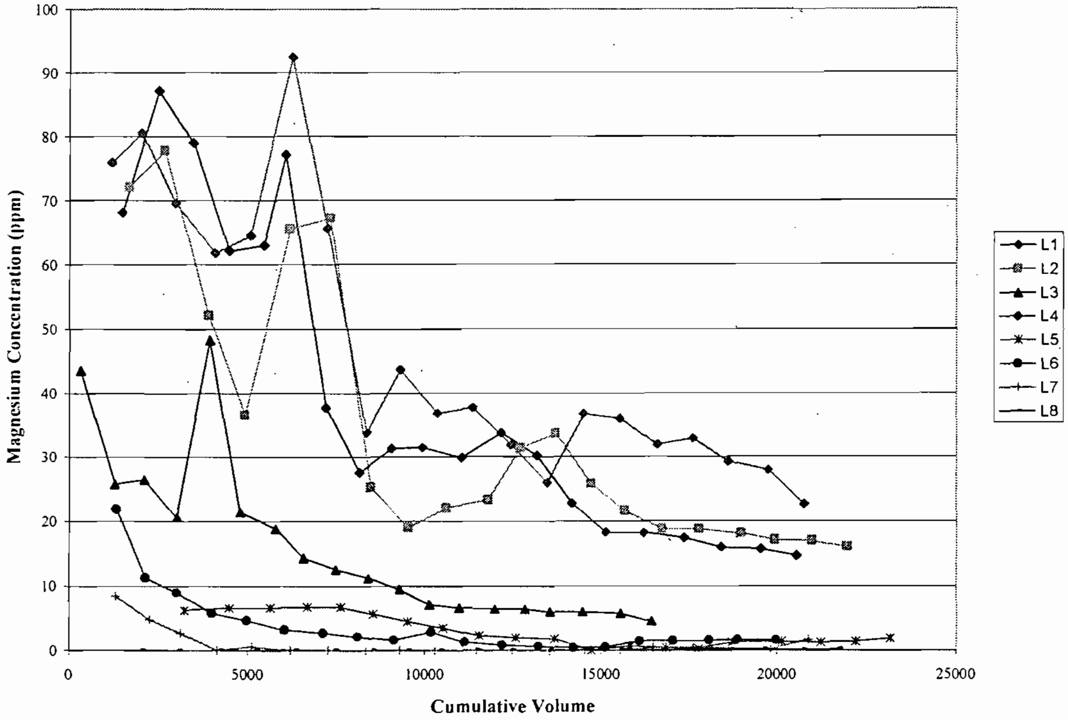

Figure B-8. Magnesium Leaching Curves.

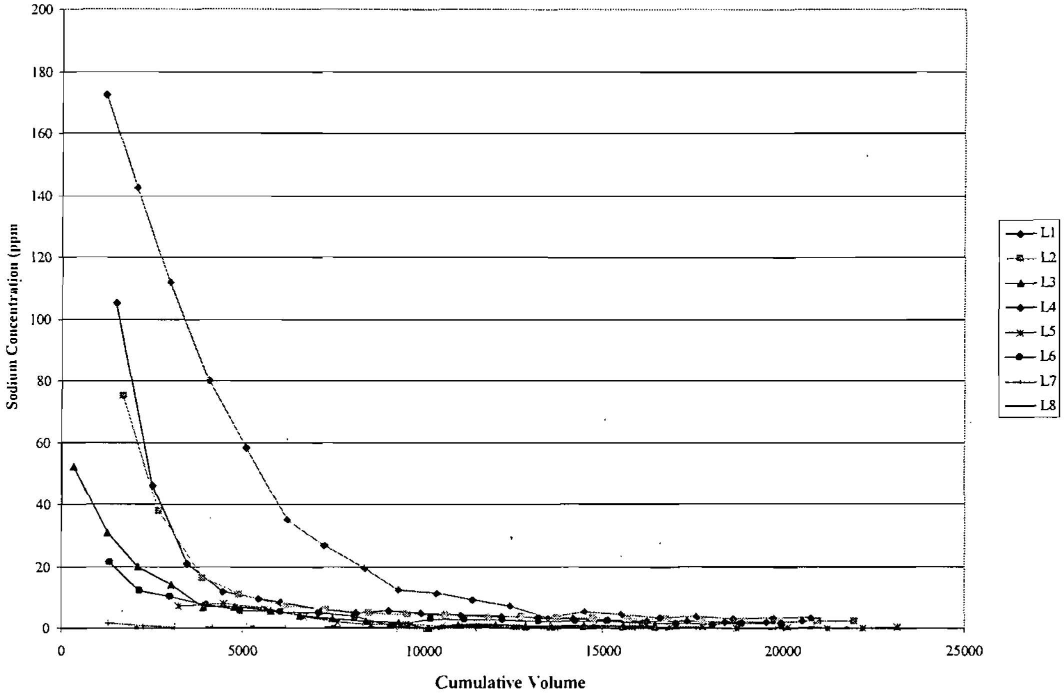

Figure B-9. Sodium Leaching Curves.

Table B-1. TDS Data

DAY	VOL ml	L1 mg/L	VOL ml	L2 mg/L	VOL ml	L3 Mg/L	VOL ml	L4 mg/L	VOL ml	L5 mg/L	VOL ml	L6 mg/L	VOL ml	L7 mg/L	VOL ml	L8 mg/L
2	500	1840	700	1500	0		300	1640	1760	420	530	440	450	460	1030	40
4	1480	860	1680	760	0		1180	1340	3220	1320	1330	280	1300	260	2010	160
6	2500	980	2660	160	330	1920	2040	740	4480	340	2140	100	2250	20	3070	0
8	3470	980	3910	980	1270	1830	2980	1120	5620	560	3020	400	3130	360	4210	180
10	4470	680	4930	660	2110	1040	4070	900	6660	280	4000	220	4145	180	5210	180
12	5440	460	6170	400	3030	720	5070	560	7600	120	4970	60	5115	0	6310	0
14	6040	540	7310	380	3940	540	6220	400	8530	180	6030	80	6185	60	7440	0
16	7190	700	8480	540	4790	600	7230	620	9510	220	7110	200	7255	80	8500	120
18	8140	460	9530	400	5780	440	8350	440	10510	160	8090	80	8325	60	9510	160
20	9050	400	10610	340	6560	300	9310	340	11540	100	9120	0	9295	0	10450	0
22	9940	420	11790	360	7480	320	10380	380	12580	120	10190	0	10295	40	11490	0
24	11040	260	12700	120	8400	280	11350	320	13670	100	11130	20	11465	0	12450	0
26	12150	420	13700	400	9300	340	12430	400	14730	160	12190	80	12485	40	13540	40
28	13170	420	14720	440	10140	380	13480	440	15820	340	13220	100	13555	60	14550	40
30	14180	300	15680	280	10980	300	14510	380	16850	60	14230	0	14555	0	15600	0
32	15140	300	16730	340	11980	340	15530	360	17780	120	15130	20	15555	0	16750	0
34	16210	300	17770	300	12840	360	16590	320	18730	80	16100	0	16485	0	17690	0
36	17350	380	18970	420	13550	500	17605	400	20140	200	17050	100	17615	40	18680	80
38	18410	160	19940	260	14470	280	18615	280	21220	60	18060	20	18695	0	19610	0
40	19550	240	20980	240	15550	320	19745	280	22185	100	18870	20	19825	0	20700	0
42	20550	260	21950	300	16430	340	20765	340	23145	140	19970	40	20875	20	21710	0

Table B-2. Alkalinity Data

DAY	VOL ml	L1 Mg/L	VOL ml	L2 Mg/L	VOL ml	L3 Mg/L	VOL ml	L4 Mg/L	VOL ml	L5 Mg/L	VOL ml	L6 Mg/L
2	500	0	700	0	0		300	0	1760	31	530	0
4	1480	380	1680	331.5	0		1180	77.5	3220	109	1330	0
6	2500	449	2660	375	330	0	2040	322	4480	120	2140	0
8	3470	425	3910	375	1270	304	2980	333	5620	120	3020	0
10	4470	430	4930	375	2110	320	4070	370	6660	125	4000	0
12	5440	402	6170	348	3030	306	5070	350	7600	127	4970	0
14	6040	376	7310	311	3940	291	6220	310	8530	131	6030	0
16	7190	364	8480	315	4790	312	7230	304	9510	125	7110	0
18	8140	330	9530	316	5780	305	8350	288	10510	123	8090	0
20	9050	337	10610	310	6560	264	9310	280	11540	121	9120	0
22	9940	352	11790	306	7480	248	10380	290	12580	121	10190	0
24	11040	340	12700	312	8400	261	11350	293	13670	120	11130	0
26	12150	327	13700	301	9300	246	12430	284	14730	120	12190	0
28	13170	292	14720	297	10140	258	13480	283	15820	120	13220	1
30	14180	287	15680	292	10980	284	14510	292	16850	115	14230	2
32	15140	261	16730	290	11980	289	15530	289	17780	112	15130	2
34	16210	241	17770	278	12840	305	16590	287	18730	112	16100	3

Table B-2 continued.

DAY	VOL ml	L1 Mg/L	VOL ml	L2 Mg/L	VOL ml	L3 Mg/L	VOL ml	L4 Mg/L	VOL ml	L5 Mg/L	VOL ml	L6 Mg/L
36	17350	229	18970	250	13550	319	17605	280	20140	120	17050	3
38	18410	217	19940	258	14470	304	18615	260	21220	109	18060	3
40	19550	225	20980	264	15550	308	19745	253	22185	110	18870	2.5
42	20550	210	21950	251	16430	291	20765	230	23145	106	19970	3

Table B-3. NPOC Data

DAY	VOL ml	L1 Mg/L	VOL ml	L2 Mg/L	VOL ml	L3 Mg/L	VOL ml	L4 Mg/L	VOL ml	L5 Mg/L	VOL ml	L6 Mg/L	VOL ml	L7 Mg/L	VOL ml	L8 Mg/L
2	500	28.55	700	19.38	0		300	36.46	1760	10.26	530	1.501	450	5.577	1030	0
4	1480	23.08	1680	18.02	0		1180	32.5	3220	34.71	1330	0.568	1300	2.437	2010	0
6	2500	16.62	2660	13.09	330	340.7	2040	29.78	4480	10.6	2140	0.999	2250	2.354	3070	1.263
8	3470	12.37	3910	9.243	1270	216.6	2980	24.0	5620	9.136	3020	0.676	3130	1.439	4210	0.303
10	4470	10.56	4930	9.405	2110	143.5	4070	18.71	6660	7.873	4000	0.612	4145	0.874	5210	0.513
12	5440	10.23	6170	6.861	3030	110.5	5070	16.02	7600	5.715	4970	0.583	5115	0.737	6310	0.343
14	6040	9.707	7310	6.338	3940	86.2	6220	12.45	8530	5.118	6030	0.586	6185	0.846	7440	0.994
16	7190	8.842	8480	6.576	4790	74.4	7230	12.52	9510	4.727	7110	0.06	7255	0.426	8500	0
18	8140	9.028	9530	6.222	5780	49.3	8350	10.79	10510	3.805	8090	0.06	8325	0.392	9510	0
20	9050	8.089	10610	5.969	6560	38.48	9310	10.62	11540	3.232	9120	0.263	9295	0.154	10450	0
22	9940	8.045	11790	6.108	7480	35.43	10380	10.95	12580	3.418	10190	0.567	10295	0.296	11490	0
24	11040	8.349	12700	6.003	8400	25.38	11350	11.06	13670	3.762	11130	0.199	11465	0.574	12450	0
26	12150	6.256	13700	5.586	9300	20.73	12430	9.107	14730	2.883	12190	0.633	12485	0.33	13540	0.066
28	13170	5.258	14720	4.786	10140	19.17	13480	8.651	15820	2.713	13220	0.144	13555	0.138	14550	0
30	14180	5.194	15680	4.234	10980	18.89	14510	8.219	16850	2.648	14230	0.179	14555	0.175	15600	0.344
32	15140	5.525	16730	4.051	11980	20.22	15530	7.748	17780	2.135	15130	0.447	15555	0.124	16750	0
34	16210		17770		12840	19.78	16590		18730		16100		16485		17690	
36	17350		18970		13550	19.2	17605		20140		17050		17615		18680	

Table B-4. pH Data

DAY	VOL	L1	VOL	L2	VOL	L3	VOL	L4	VOL	L5	VOL	L6	VOL	L7	VOL	L8
2	500		700		0		300		1760		530		450		1030	
4	1480	6.9	1680	7	0		1180	6.12	3220	6.84	1330	2.88	1300	2.97	2010	3.16
6	2500	7.15	2660	7.01	330		2040	7.2	4480	7	2140	3.5	2250	3.53	3070	3.47
8	3470	7.25	3910	7.24	1270	6.67	2980	7.34	5620	7.09	3020	3.85	3130	3.57	4210	3.45
10	4470	7.25	4930	7.29	2110	7.09	4070	7.44	6660	6.96	4000	4.24	4145	4.05	5210	4.2
12	5440	7.17	6170	7.14	3030	7.06	5070	7.38	7600	6.95	4970	4.57	5115	4.04	6310	4.00
14	6040	7.27	7310	7.26	3940	7.22	6220	7.38	8530	7.08	6030	5.03	6185	4.28	7440	4.03
16	7190	7.14	8480	7.13	4790	7.38	7230	7.4	9510	6.97	7110	5.28	7255	4.22	8500	4.15
18	8140	7.18	9530	7.17	5780	7.3	8350	7.31	10510	6.97	8090	5.32	8325	4.19	9510	4.08
20	9050	7.25	10610	7.27	6560	7.09	9310	7.37	11540	7.09	9120	5.93	9295	4.3	10450	4.12
22	9940	7.07	11790	7.11	7480	7.1	10380	7.17	12580	7.03	10190	6.38	10295	4.4	11490	4.25
24	11040	7.15	12700	7.17	8400	7.16	11350	7.26	13670	7.04	11130	7.08	11465	4.6	12450	4.15

Table B-4. Continued

DAY	VOL	L1	VOL	L2	VOL	L3	VOL	L4	VOL	L5	VOL	L6	VOL	L7	VOL	L8
26	12150	7.18	13700	7.18	9300	7.09	12430	7.31	14730	7.12	12190	7.1	12485	4.56	13540	4.1
28	13170	7.16	14720	7.11	10140	7.03	13480	7.11	15820	7.07	13220	7.25	13555	4.5	14550	4.18
30	14180	7.25	15680	7.18	10980	7	14510	7.18	16850	7.05	14230	7.39	14555	4.51	15600	4.17
32	15140	7.24	16730	7.13	11980	6.94	15530	7.2	17780	6.97	15130	7.54	15555	4.79	16750	4.2
34	16210	7.35	17770	7.24	12840	6.91	16590	7.28	18730	6.99	16100	6.85	16485	4.85	17690	4.19
36	17350	7.3	18970	6.94	13550	6.96	17605	7.29	20140	7	17050	7.27	17615	5.04	18680	4.23
38	18410	7.24	19940	7.2	14470	6.84	18615	7.2	21220	6.93	18060	7.52	18695	5	19610	4.25
40	19550	7.19	20980	7.14	15550	6.8	19745	7.19	22185	6.92	18870	7.21	19825	4.92	20700	4.17
42	20550	7.32	21950	7.19	16430	6.86	20765	7.22	23145	6.97	19970	7.12	20875	4.9	21710	4.3

Table B-5. Conductivity

DAY	VOL	L1	VOL	L2	VOL	L3	VOL	L4	VOL	L5	VOL	L6	VOL	L7	VOL	L8
2	500	4270	700	2580	0		300	9950	1760	645	530	4380	450	6200	1030	2930
4	1480	1551	1680	1265	0		1180	1850	3220	344	1330	985	1300	782	2010	464
6	2500	1202	2660	1062	330	5380	2040	1517	4480	316	2140	381	2250	326	3070	154
8	3470	1019	3910	845	1270	1494	2980	1191	5620	308	3020	270	3130	205	4210	80
10	4470	904	4930	783	2110	1126	4070	1114	6660	276	4000	173	4145	115	5210	31
12	5440	867	6170	762	3030	934	5070	945	7600	278	4970	146	5115	99	6310	41
14	6040	802	7310	688	3940	714	6220	777	8530	273	6030	121	6185	73	7440	32
16	7190	786	8480	660	4790	693	7230	684	9510	257	7110	101	7255	68	8500	25
18	8140	718	9530	657	5780	656	8350	673	10510	257	8090	91	8325	59	9510	26
20	9050	711	10610	632	6560	573	9310	635	11540	247	9120	80	9295	49	10450	23
22	9940	692	11790	611	7480	575	10380	602	12580	232	10190	70	10295	46	11490	24
24	11040	674	12700	584	8400	560	11350	599	13670	237	11130	67	11465	39	12450	23
26	12150	658	13700	583	9300	525	12430	593	14730	230	12190	57	12485	33	13540	23
28	13170	606	14720	597	10140	535	13480	612	15820	221	13220	52	13555	34	14550	20
30	14180	577	15680	564	10980	530	14510	576	16850	217	14230	51	14555	32	15600	20
32	15140	531	16730	531	11980	548	15530	612	17780	220	15130	51	15555	26	16750	19
34	16210	496	17770	540	12840	581	16590	589	18730	224	16100	49	16485	28	17690	26
36	17350	476	18970	541	13550	577	17605	570	20140	211	17050	46	17615	24	18680	19
38	18410	445	19940	512	14470	574	18615	536	21220	205	18060	43	18695	23	19610	16
40	19550	434	20980	516	15550	573	19745	536	22185	206	18870	44	19825	26	20700	16
42	20550	428	21950	512	16430	558	20765	494	23145	207	19970	41	20875	25	21710	17

Table B-6. DO Data

DAY	VOL	L1	VOL	L2	VOL	L3	VOL	L4	VOL	L5	VOL	L6	VOL	L7	VOL	L8
2	500	7.7	700	7.62	0		300	7.79	1760	6.2	530	8.08	450	8.4	1030	8.28
4	1480	6.4	1680	6.14	0		1180	6.6	3220	5.36	1330	7.6	1300	8.17	2010	8.34
6	2500	5.8	2660	6.05	330	5.44	2040	6.04	4480	3.27	2140	6.82	2250	8.34	3070	8.35
8	3470	4.75	3910	5.32	1270	1.55	2980	5.31	5620	4.04	3020	5.57	3130	8.9	4210	8.8
10	4470	4.67	4930	4.86	2110	1.72	4070	5.39	6660	3.31	4000	4.97	4145	8.6	5210	8.64

Table B-6. Continued

DAY	VOL	L1	VOL	L2	VOL	L3	VOL	L4	VOL	L5	VOL	L6	VOL	L7	VOL	L8
12	5440	5.23	6170	5.25	3030	2.88	5070	5.46	7600	3.61	4970	4.54	5115	8.67	6310	8.65
14	6040	7.25	7310	5.84	3940	4.52	6220	6.6	8530	5.13	6030	6.05	6185	8.66	7440	8.78
16	7190	6.07	8480	5.41	4790	1.7	7230	6.21	9510	4.25	7110	6.37	7255	8.46	8500	8.41
18	8140	6.5	9530	5.53	5780	1.5	8350	5.88	10510	4.03	8090	6.41	8325	8.56	9510	8.64
20	9050	6.81	10610	6.27	6560	4.33	9310	6.84	11540	5.27	9120	6.97	9295	8.68	10450	8.68
22	9940	6.2	11790	6	7480	6.05	10380	5.7	12580	4.73	10190	6.75	10295	9.08	11490	8.46
24	11040	5.51	12700	5.72	8400	1.8	11350	5.71	13670	4.63	11130	6.58	11465	8.38	12450	8.38
26	12150	6.13	13700	6.01	9300	2.36	12430	6.43	14730	5.63	12190	7.25	12485	8.5	13540	8.5
28	13170	6.93	14720	6.35	10140	2.65	13480	6.57	15820	4.64	13220	8.54	13555	8.48	14550	8.48
30	14180	7.3	15680	6.7	10980	2.51	14510	6.7	16850	4.36	14230	7.57	14555	8.62	15600	8.55
32	15140	7.8	16730	6.48	11980	2.4	15530	6.62	17780	5.03	15130	7.57	15555	8.78	16750	8.5
34	16210	8.03	17770	7	12840	3.17	16590	6.93	18730	5.03	16100	7.77	16485	8.85	17690	8.6
36	17350	8	18970	7.07	13550	3.38	17605	7.18	20140	5.03	17050	7.87	17615	8.6	18680	8.49
38	18410	7.27	19940	6.47	14470	2.38	18615	6.62	21220	5.13	18060	7.42	18695	8.27	19610	8.31
40	19550	7.72	20980	6.78	15550	3.55	19745	7.5	22185	5.02	18870	7.75	19825	8.53	20700	8.63
42	20550	7.85	21950	6.91	16430	5.03	20765	7.45	23145	5.5	19970	7.34	20875	8	21710	7.9

Table B-7. ORP Data

DAY	VOL	L1	VOL	L2	VOL	L3	VOL	L4	VOL	L5	VOL	L6	VOL	L7	VOL	L8
2	500	608	700	592	0		300	631	1760	472	530	623	450	630	1030	680
4	1480	472	1680	476	0		1180	493	3220	558	1330	594	1300	606	2010	624
6	2500	500	2660	514	330	566	2040	432	4480	537	2140	585	2250	593	3070	618
8	3470	227	3910	226	1270	-30	2980	249	5620	560	3020	582	3130	507	4210	590
10	4470	451	4930	468	2110	-98	4070	194	6660	473	4000	467	4145	570	5210	572
12	5440	522	6170	518	3030	-133	5070	225	7600	520	4970	440	5115	529	6310	588
14	6040	530	7310	535	3940	-74	6220	560	8530	570	6030	611	6185	645	7440	613
16	7190	514	8480	497	4790	462	7230	476	9510	550	7110	559	7255	608	8500	614
18	8140	509	9530	527	5780	-53	8350	518	10510	530	8090	572	8325	600	9510	627
20	9050	344	10610	350	6560	-10	9310	517	11540	527	9120	580	9295	590	10450	598
22	9940	538	11790	527	7480	-35	10380	358	12580	558	10190	575	10295	594	11490	594
24	11040	324	12700	332	8400	5	11350	391	13670	541	11130	560	11465	617	12450	641
26	12150	516	13700	514	9300	50	12430	527	14730	400	12190	430	12485	580	13540	599
28	13170	518	14720	516	10140	25	13480	515	15820	572	13220	585	13555	607	14550	604
30	14180	517	15680	510	10980	46	14510	521	16850	566	14230	579	14555	615	15600	617
32	15140	520	16730	515	11980	484	15530	559	17780	478	15130	595	15555	629	16750	648
34	16210	548	17770	547	12840	489	16590	558	18730	537	16100	547	16485	649	17690	658
36	17350	515	18970	510	13550	495	17605	516	20140	564	17050	590	17615	536	18680	558
38	18410	511	19940	475	14470	525	18615	542	21220	580	18060	615	18695	643	19610	656
40	19550	537	20980	540	15550	550	19745	561	22185	583	18870	600	19825	628	20700	637
42	20550	512	21950	515	16430	568	20765	577	23145	588	19970	604	20875	633	21710	640

APPENDIX C

BMP Document

Management of Solid Waste from Abrasive Blasting Operations:

A Guide for Industry, Consultants, and Regulators

Prepared by:
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ABRASIVE BLASTING

The process of abrasive blasting is used to remove paints and other coatings from primarily metal surfaces. The abrasive blasting process is an efficient means of surface treatment because as the old coatings are removed, the surface is prepared for the application of additional coatings. There are many types of media in use including some of the most common which are: silica sand, coal slag, plastic media, glass bead, steel shot and walnut shells.

After abrasive blasting a surface, a material remains that contains the original blast media, as well as the coatings removed from the surface.

WHAT INDUSTRIES PRACTICE ABRASIVE BLASTING?

A number of industries practice abrasive blasting. These industries include:

- Ship Maintenance Facilities
- Bridge Maintenance
- The Military
- Autoshops
- Metal Fabricators
- Airports
- Rail yards

Abrasive blasting may be performed by an individual industry, or by abrasive blasting contractors.

WHAT IS A SOLID WASTE?

The United States Environmental Protection Agency has defined the term solid waste as follows.

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

In short, a solid waste is anything that is discarded as a result of human activities. By this definition, used abrasive blasting media is defined as a solid waste, and must be managed according to appropriate federal, state, and local solid waste regulations.

WHY IS PROPER MANAGEMENT OF SOLID WASTE IMPORTANT?

The improper management of solid waste may pose a threat to human health and the environment. In some cases, a solid waste may be deemed hazardous, and thus require very controlled management. Even in cases when not hazardous, the waste must be managed in a way that it is not a threat to humans who may come into contact with the waste or to groundwater supplies.

In the case of abrasive blasting waste, some paints contain heavy metals that can be harmful to human health and the environment. Proper management is thus required. While added care may result in an increase in costs, growing recycling opportunities are available to manage used ABM solid waste.

USING THIS DOCUMENT

This document outlines the steps necessary for the proper management of solid waste generated during the process of abrasive blasting. The information presented is derived from current environmental regulations and policy toward solid waste management, and from current industry practices.

The Quick Reference section is provided for the convenience of locating answers to frequently asked questions.

Quick Reference Section

Is my waste ABM hazardous?

See page **3**

What kind of hazardous waste generator am I?

See page **4**

What are my requirements as a hazardous waste generator?

See page **4**

What if my ABM is not hazardous?

See page **5**

Where can I dispose of my non-hazardous waste ABM

See page ***7***

Can I land apply my waste ABM?

See page **7**

What tests do I need to run on my waste ABM if I leave it on site?

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Can I use my knowledge of the process to leave my waste on site?

See page **8**

How can I reduce the amount of ABM waste I produce?

See page **8**

How can I recycle my waste ABM?

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Who should I contact if I have questions about my waste ABM?

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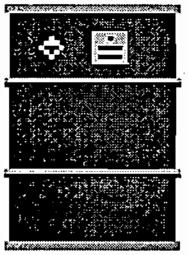


THE DEFINITION OF HAZARDOUS WASTE

A hazardous waste is defined in the code of regulations (CFR), section 40, part 261. A waste is hazardous if it is listed in the CFR or it exhibits characteristics of corrosivity, reactivity, ignigtability, or toxicity. Each characteristic is specifically defined in 40 CFR 261.

Waste ABM is not listed as a hazardous waste in the CFR and typically waste ABM will not exhibit any of the characteristics listed above, except for toxicity due to heavy metal content. This characteristic will be discussed in detail here.

If a generator questions whether the waste ABM generated is exhibiting any other hazardous characteristic, 40 CFR 261 should be referenced or a regulatory agency contacted.

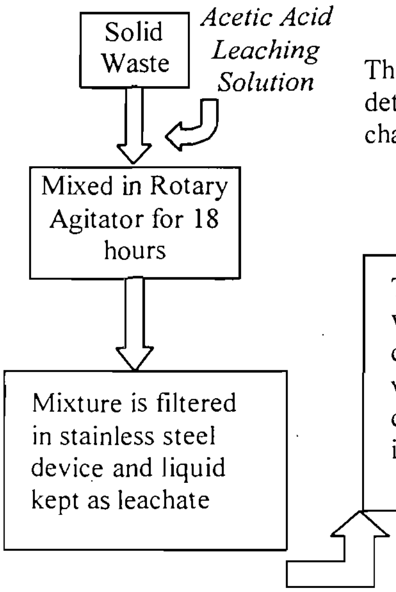
IS MY ABRASIVE BLASTING WASTE A HAZARDOUS WASTE?

The test required by federal regulations to determine if a waste exhibits hazardous characteristics is the Toxicity Characteristic Leaching Procedure (TCLP)-see text box below. Every generation of new waste ABM must be tested.

The TCLP test must be run by a lab with a FDEP approved comprehensive quality assurance plan. If this test is run on the waste and the leachable metals are at or above limits set in 40 CFR 261, the waste is deemed hazardous. The following table gives the most common metals found in ABM and their TCLP limits.

Table 1. Toxicity Characteristic Maximum Contaminant Concentrations

Heavy Metal	**Regulatory Level (mg/l)**
Arsenic	5.0
Barium	100.0
Cadmium	1.0
Chromium	5.0
Lead	5.0
Mercury	0.2
Selenium	1.0
Silver	5.0



What is the TCLP Test?

The TCLP test is a procedure used by the U.S. EPA to determine whether a solid waste is hazardous by toxicity characteristics.

This leachate contains all of the contaminants which leached off the waste. The amounts of these contaminants are measured in mg/L and compared with the TCLP limits in 40 CFR 261. Table 1 contains metals commonly found or examined for in waste ABM.

REQUIREMENTS OF HAZARDOUS WASTE GENERATORS

Requirements for generators of hazardous waste differ by the quantity of hazardous waste which is produced. All hazardous waste generated in a month must be totaled to determine generator status, not just hazardous waste ABM. Any facility that stores hazardous waste ABM in piles, must do so in a containment building certified by a professional engineer and comply with the Large Quantity Generator rules regardless of generation rate.

Conditionally Exempt Small Quantity Generators- generate less than 100kg (220lb) of hazardous waste per month and accumulates less than 1000kg (2,200lb) of hazardous waste at any time.

Small Quantity Generators (SQG)- generate more than 100kg (220lb), but less than 1000kg (2,200lb) of hazardous waste per month and accumulate less than 6000kg (13,200lb) of hazardous waste at any time.

Large Quantity Generators (LQG)- generate more than 1000kg (2,200lb)of hazardous waste per month.

All hazardous waste generator classifications and requirements are listed in 40 CFR 262. This regulation should be referenced if there is any question to generator status or if a generator produces acutely hazardous waste as defined by 40 CFR 262.

Once generator status has been established, the requirements must be met for handling the hazardous waste. If a generator treats hazardous waste to render it non-hazardous, a waste analysis plan must be submitted to FDEP as well as required compliance with LQG/SQG regulations.

Containers All hazardous waste including waste blast that fails TCLP for any metals must be placed in a non-leaking, sealable container in good condition. All hazardous waste containers must be kept closed except when wastes are added or removed.

Storage *Large Quantity Generators* may not store waste over 90 days, *Small Quantity Generators* may not store waste more than 180 days, and *Conditionally Exempt Small Quantity Generators* can store waste as long as they need too as long as the amount does not exceed 1000kg. **HAZARDOUS WASTE ABM MAY NOT BE STORED ON THE GROUND AT ANY TIME.**

Labels All containers must have a hazardous waste label which identifies the waste, includes a federal waste code number, the accumulation start date, and the generators name and address. See Label example below.

Inspections of waste containers should be performed each week and records should be kept of inspections and all other transactions for 3-5 years.

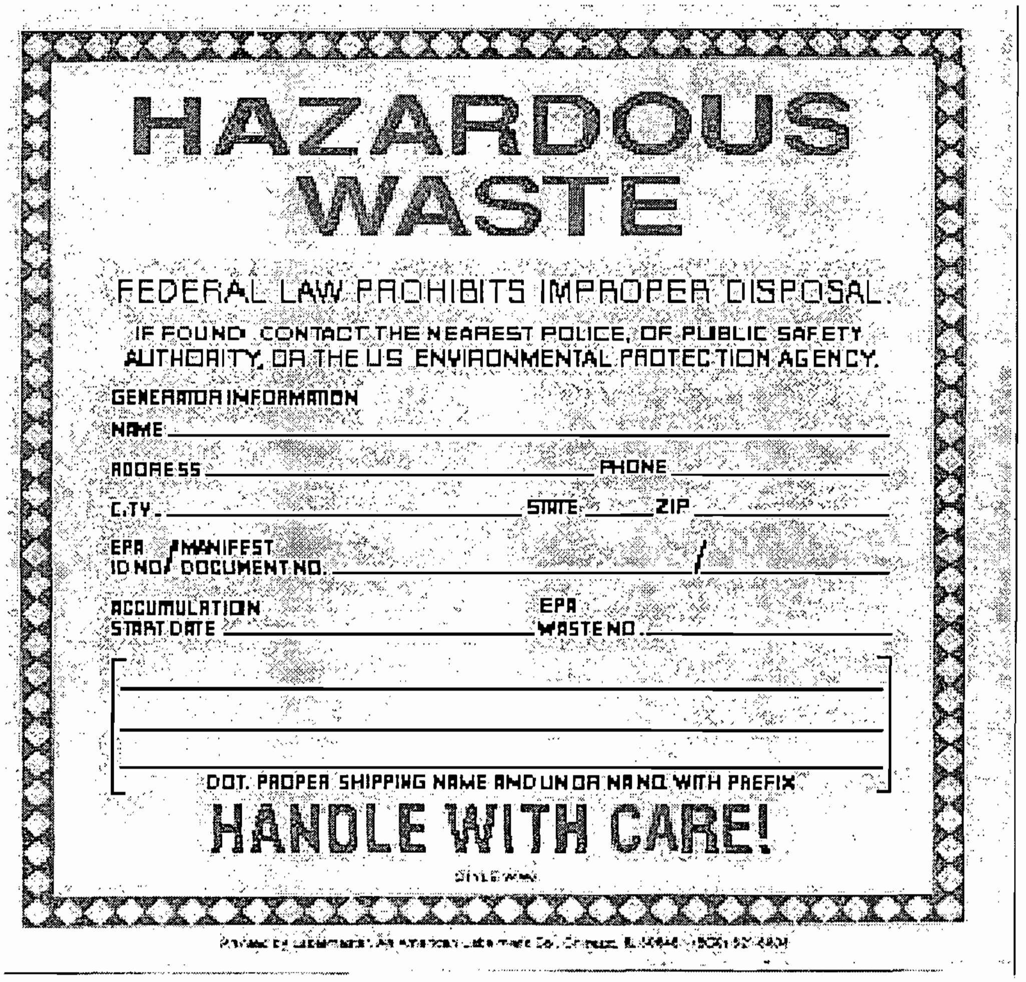
Transportation of hazardous waste must be performed each week by certified persons with permits from regulatory agencies. Detailed shipping papers, called manifests, must be used for all shipments of any hazardous waste. The manifest records must be kept for 3-5 years.

Training must be given to all employees as to how to properly handle all wastes generated.

Disposal Hazardous waste may only be disposed of in permitted Treatment, Storage and Disposal facilities. Hazardous waste must be tracked and accounted for from "cradle to grave."

If a generator is not currently classified as a hazardous waste generator and finds that some waste ABM is hazardous, state and local regulators need to be notified and a hazardous waste contractor contacted to arrange for proper treatment and disposal of the waste.

LABEL EXAMPLE



HAZARDOUS WASTE

FEDERAL LAW PROHIBITS IMPROPER DISPOSAL.

IF FOUND, CONTACT THE NEAREST POLICE, OR PUBLIC SAFETY AUTHORITY, OR THE U.S. ENVIRONMENTAL PROTECTION AGENCY.

GENERATOR INFORMATION

NAME ____________________

ADDRESS ____________________ PHONE ____________________

CITY ____________________ STATE ______ ZIP ____________

EPA ID NO./ MANIFEST DOCUMENT NO. ____________________ / ______

ACCUMULATION START DATE ____________________ EPA WASTE NO. ____________________

DOT. PROPER SHIPPING NAME AND UN OR NA NO. WITH PREFIX

HANDLE WITH CARE!

DISPOSAL AND RECYCLING

The cost of management is greatly reduced when a solid waste is not hazardous by regulation. The requirements for proper management do not end however.

Waste ABM must still be managed in a manner to minimize impact to human health and the environment. While no specific regulation exists for the management of solid waste from abrasive blasting operations, a number of regulations and policy guidelines apply to non-hazardous solid waste in general.

Management decisions must be made as to how to best manage the solid waste on site (storage) and what the final disposition of the waste will be. The two primary options are disposal and recycling. In both cases, measure must be taken to minimize risk to human health and the environment.

EVALUATION OF ENVIRONMENTAL IMPACT

A number of factors must be considered when evaluating the potential risk to human health and the environment.

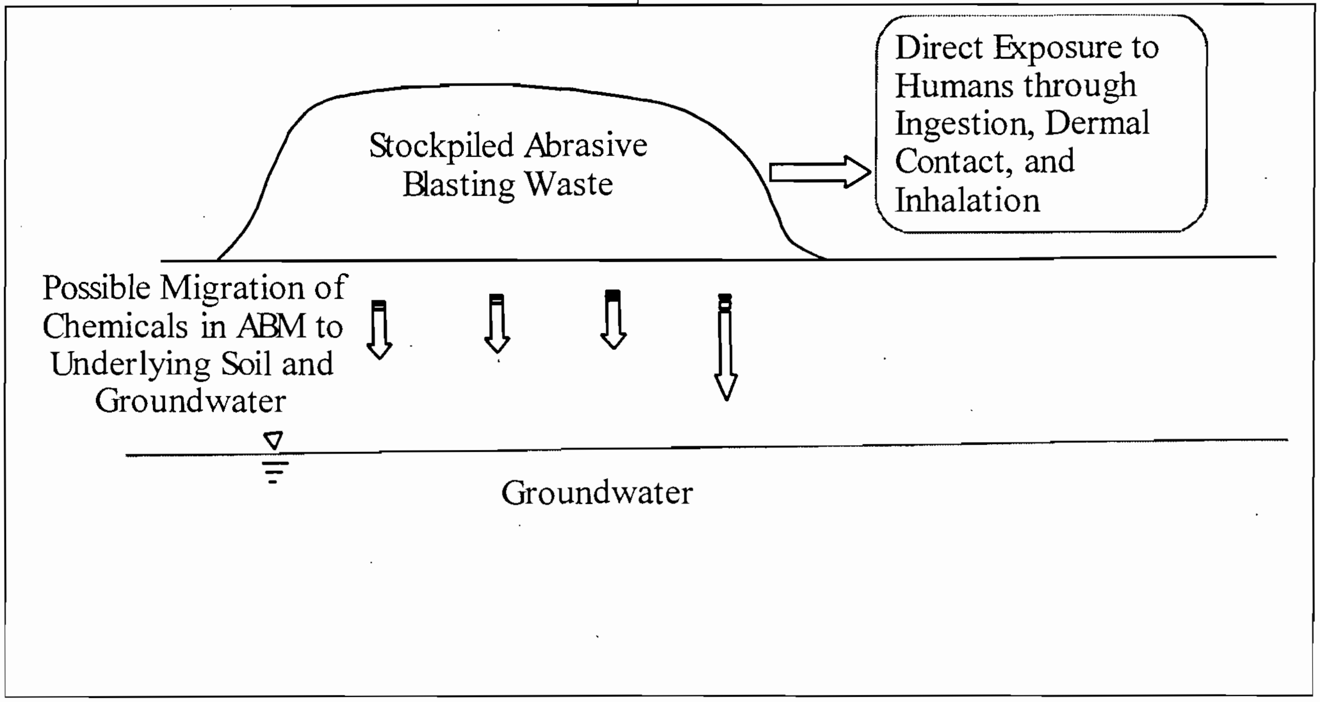
The potential exposure of a human to the waste must be examined. If the possibility exists that human exposure might result, either through direct ingestion, inhalation, or dermal contact, then the risk of such exposure must be evaluated.

This risk must consider the waste, not only in its present state, but also for the waste at some future period in time (e.g. after a site has been closed). A detailed, site-specific risk analysis may be performed, but in most cases a set of generic assumptions will be used to determine what contaminant concentration level is safe for a given use.

The possibility of chemicals leaching from the waste to the groundwater must also be considered. If a waste is placed in a manner where rainfall will percolate and result in the production of leachate, the leaching potential of the waste must be evaluated.

Impact to Human Health

Florida guidelines for assessing the impact to human health are the application of risk-based standards for the clean up of waste



sites. These standards are based on the waste placement in the top 2 feet of the surface and the total metal concentration in the waste in units of mg/kg. These same numbers can be applied to the application of a waste to the land.

These guidelines are referred to as the Florida Soil Cleanup Goals. The residential soil cleanup goals are more restrictive and would be applied to areas where people live and have unrestricted access (e.g. parks). The industrial goals are less stringent because human exposure should be less in these areas. Table 2 contains the concentration limits for the soil cleanup goals for common metals found in ABM.

Table 2. Florida Soil Cleanup Goals for Heavy Metals

Heavy Metal	Residential Goal (mg/kg)	Industrial Goal (mg/kg)
Arsenic	0.8	3.7
Aluminum	75,000	-
Barium	5,200	84,000
Cadmium	37	600
Chromium	290	430
Cobalt	4,700	110,000
Lead	500	1,000
Mercury	23	480
Nickel	1,500	26,000
Selenium	390	9,900
Silver	390	9,000
Tin	44,000	670,000
Vanadium	490	4,800
Zinc	23,000	560,000

Impact to Groundwater

The impact to groundwater must be assessed for a waste in the environment. The test which simulates rainfall percolating through waste over an extended period of time is the synthetic precipitation leaching procedure (SPLP). This test is exactly like the TCLP in process, but uses an extraction fluid made from nitric and sulfuric acids

The metal concentrations found in the leachate of this test may be compared with Florida's Groundwater Guidance concentrations. If the metal concentrations in the leachate are above the guidance levels, the waste is determined to have the potential to affect groundwater quality.

Table 3. Florida Groundwater Guidance Concentrations for Heavy Metals

Heavy Metal	Regulatory Level (mg/l)
Arsenic	0.050
Aluminum	0.200
Barium	2.00
Cadmium	0.005
Chromium	0.100
Copper	1.00
Iron	0.300
Lead	0.015
Mercury	0.002
Nickel	0.100
Selenium	0.050
Silver	0.100
Tin	4.20
Vanadium	0.049
Zinc	5.00

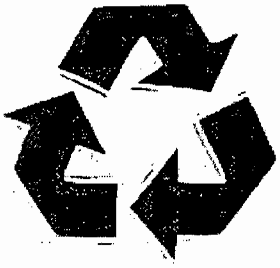
DISPOSAL IN LANDFILLS

A number of options are available in regard to disposal of waste ABM in solid waste landfills. These options include disposal in a Class I or Class III sanitary landfill, or disposal on site.

A "knowledge of the process," meaning the generator knows what is in the material being blasted, may be acceptable for determining disposal options once the original waste has been tested and the same media is used on similar coatings to generate waste. Contact your local regulator if you want to use your "knowledge of the process." This can greatly reduce analytical costs for small blasting operations, however disposal and recycling facilities may still require analytical test data.

Class I Sanitary Landfills A class I sanitary landfill is an engineered facility designed to receive and contain non-hazardous solid waste. Class I facilities are the repository of most household garbage, as well as other materials such as sludge and some industrial wastes. These facilities are lined and equipped to remove and treat leachate.

For ABM to be disposed of in a Class I landfill, no other regulatory requirements would need to be met other than the waste not being hazardous. The operator of a landfill is not required to accept a waste, however, and proof of passing TCLP may be required. Some facilities may readily accept used ABM as it may serve as an excellent source of alternative daily cover. These facilities may ever lower or waive the tipping fee if the waste is useful to them



Class III Sanitary Landfills A class III landfill is used for the disposal of inert materials that will not leach contaminants into the environment. A class III landfill may only be used for disposal if the waste will not constitute a risk to groundwater quality. This means that a TCLP leaching test should be run on the waste, and the leachate contaminant results compared to the Groundwater Guidance concentrations.

The type of leaching test used may either be TCLP, or the SPLP test. It is important to specify to the laboratory that is testing the leachate, however, that the tests be performed at or below detection limits below the groundwater guidance concentrations. The TCLP limits are much greater than the groundwater guidance concentrations, and failure to specify may result in costly reanalysis.

Disposal On-Site A final disposal option is the disposal of the material on site. For a material to be recycled or "disposed" on-site, the material must not possess characteristics of a solid waste. Therefore, it must pose neither a risk to human health nor the environment through direct exposure, or a risk to groundwater quality.

For disposal on site two separate analyses of the waste must be run: A total metal analysis and a leaching analysis.

The waste must fall below the direct exposure limits in the soil clean up goals, and also be below groundwater guidance concentrations in the leaching tests used (most likely SPLP).

REUSE

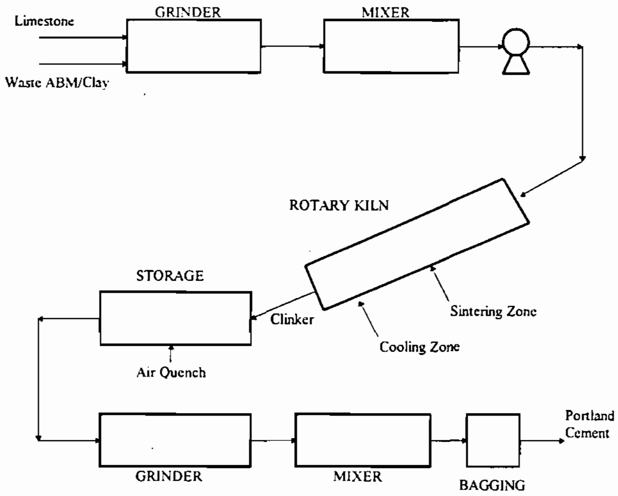
There are advantages and possibilities for recycling used ABM. One potential way to cut down on costs of disposal would be to use a reusable abrasive blasting media. Media that can be screened and reused include garnet, aluminum oxide, steel shot, sponge media, and plastic media. Reuse of reclaimed media can concentrate a waste stream creating a smaller volume, but with more contamination.

Recycling

Recycling and beneficial reuse options for the ABM waste after generation are also available.

Production of Portland Cement This recycling option is excellent for coal slag ABM waste. The media contains alumina, silica, and iron, which are feedstock for a cement kiln. A generator of non-hazardous waste ABM can pay much lower disposal costs to have the cement kiln take the waste and the cement kiln is getting paid to take a feedstock they would normally have to purchase.

Not only must the waste ABM be non-hazardous, it must also be chemically compatible as a feedstock in the cement-making process. Calcium silicate based additives to stabilize heavy metals are compatible to the process, however other additives such as phosphates and fluorides are not. The waste ABM is fed into the cement making process right at the beginning. The chemical process of making the cement changes the ABM into a new product, therefore the waste does not exist anymore. See diagram of cement making process.



Aggregate in Concrete Waste ABM may also be used as aggregate in Portland Cement concrete or Asphalt concrete. These concretes are a mixture of a binder (cement or asphalt) and an aggregate. Waste ABM which is angular in shape is better suited to asphalt concrete. These concretes can be used in non-structural situations, such as roadways and sidewalks.

If the ABM waste is high in contaminants, problems with setting may occur, but most non-hazardous ABM used as aggregate should set fine.

Construction Fill Waste ABM used as construction fill would have to meet the same standards as for disposal on-site (no solid waste characteristics). This includes proving that the waste will cause no harm to humans through direct exposure and no harm to the environment through groundwater contamination. As before, if both of these requirements are met, the waste may be used as construction fill, however physical properties of the waste may need to be examined for this recycling option.

Contact Information

Federal Contacts	
RCRA Hotline	(800)-424-9346
State Contacts	
Florida Bureau of Solid and Hazardous Waste	(850)-488-0300
District Contacts	
Solid Waste Section	
Northwest District	
Pensacola	(850)-444-8360
Northeast District	
Jacksonville	(904)-448-4300
Central District	
Orlando	(407)-894-7555
Southwest District	
Tampa	(813)-744-6125
South District	
Fort Myers	(941)-332-6975
Southeast District	
West Palm Beach	(561)-681-6770

Department of Environmental Protection

A Guide on Hazardous Waste Management

CONDITIONALLY EXEMPT SMALL QUANTITY GENERATORS

INTRODUCTION

Many businesses, both large and small use hazardous materials in their processes. Many of these processes produce wastes. A portion of these wastes may be hazardous. The method a business manager employs to manage hazardous waste will have a direct influence on business profits and future liabilities for the property, the business, and its owners.

The purpose of this paper is to provide basic information to industry and public agencies that may be generators of small quantities of hazardous waste and to inform them of their responsibilities for proper hazardous waste management.

HOW CAN I DETERMINE IF I HAVE HAZARDOUS WASTE?

All generators of waste materials are required by law to identify and evaluate their waste. Evaluating waste streams means determining whether or not the waste is hazardous. Evaluate each waste you produce using Step 1 below to determine whether you are a generator.

Step 1: Evaluate Your Waste

First, inventory and assemble information about your waste. An inventory consists of identifying all wastes that your business discards including sewered and recycled waste, unusable products, and by-products.

Material Safety Data Sheets (MSDSs) for your raw materials can be used to help identify your waste. Your Trade Association may be a good source of information. They can provide assistance for evaluating your wastes as well as assistance in handling, packaging and labeling your waste. If you have no information about your waste, it may be necessary to have the waste analyzed by a laboratory.

To determine whether your waste is hazardous, answer the following questions for each waste on your inventory.

1. Is the waste exempt from regulation? (i.e., recycled used oil, lead acid batteries that are reclaimed, domestic sewage, permitted industrial discharges, see Table 1)
2. Is the waste listed as a hazardous waste? (i.e., spent halogenated and certain non-halogenated solvents, see Table 2)
3. Is the waste hazardous because it exhibits a hazardous characteristic? (ignitable, corrosive, reactive, toxic, see Table 3)

Call DEP for a list of EPA Hazardous Waste codes for waste streams commonly generated.

If your waste is not exempt and you answered yes to questions 2 or 3 for any waste produced then your business is a generator of hazardous waste.

Step 2:Determine Generator Size

The amount of all hazardous waste generated or accumulated at your business will determine which category you fit in (see Table 4). Each category has its own requirements for waste management. If you generate less than 100 kg (220 lbs.) per month of hazardous waste and no more than 1kg (2.2 lbs.) of acutely hazardous waste in a calendar month, you are a conditionally exempt small quantity generator (CESQG) and the RCRA hazardous waste regulations require you to:

1. Determine whether the wastes you generate are regulated as hazardous waste under RCRA law (see Steps 1 & 2).
2. Keep the amount of hazardous waste you generate in one month under 220 pounds or under 2.2 pounds for an acute hazardous waste (i.e., arsenic and cyanide compounds) in one month.
3. Keep the amount of hazardous waste you have accumulated on your site under 2,200 pounds.
4. Dispose of your waste only at a site that is approved by the Florida Department of Environmental Protection (DEP).[1]

Step 3:Record Keeping

A conditionally exempt small quantity generator that chooses to send its hazardous waste to an off-site treatment, storage or disposal facility shall document delivery of its hazardous waste through written receipts and other records, which are retained for at least three years. The written receipts and other records shall include:

1. Name and address of the generator and the treatment, storage or disposal facility,
2. Type hazardous waste delivered,
3. Amount of hazardous waste delivered, and the
4. Date of shipment.

For additional information on the Small Quantity Generator requirements call or write for:

FLORIDA'S HANDBOOK FOR SMALL QUANTITY GENERATORS OF HAZARDOUS WASTE

Small Quantity Generator Program Coordinator, MS4555
Florida Department of Environmental Protection Hazardous
Waste Management Section
2600 Blair Stone Road Tallahassee, Florida 32399-2400
Phone: (850) 488-0300
www.dep.state.fl.us

April 7, 1998

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[1] Solid Waste facilities cannot accept these wastes pursuant to 62-701.300 F.A.C. Many counties have hazardous waste collection centers that will accept hazardous waste from conditionally exempt small quantity generators for a reduced fee during scheduled collections. Contact your county solid waste agency or DEP at (850) 488-0300 for more information.

Department of Environmental Protection

A Guide on Hazardous Waste Management

SMALL QUANTITY GENERATORS

INTRODUCTION

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RESOURCE CONSERVATION AND RECOVERY ACT

The Resource Conservation and Recovery Act (RCRA) was enacted by Congress in 1976 to protect public health and the environment from improper management of hazardous waste. RCRA was primarily written to regulate hazardous waste managed by the larger generator. Since the initial enactment, RCRA has been amended to regulate the previously exempted small quantity generator. The State of Florida has adopted by reference the federal regulations governing the small quantity generator.

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The Following Steps Apply to 100-1,000 Kg/month Small Quantity Generators

Step 3:Obtain an EPA Identification number

As a small quantity generator, you are required to obtain an EPA/DEP identification number by completing and submitting EPA Form 8700-12, Notification of Waste Activity. These forms can be obtained from DEP Tallahassee office or from any of the DEP district offices. The EPA/DEP I.D. number is site specific, so if you move to a new location you must get a new EPA/DEP I.D. number.

Step 4:Place Waste in a Labeled, Leak proof Container

The label must include:

1. The words "Hazardous Waste-Federal Law Prohibits Improper Disposal. If found, contact the nearest police or public safety authority or the U.S. Environmental Protection Agency";
2. Generator's Name and Address;
3. Manifest Document Number.
4. The container should also include:

- Description of the waste; and,
- The date the waste was first put into the container (accumulation start date).

In addition, you must follow DOT labeling requirements when you ship your container off-site. Your transporter should be familiar with these requirements, otherwise, call the Florida Department of Transpiration, Hazardous Materials Compliance Officer at 850-488-6289.

Step 5:Store Waste Properly; Accumulate Up To The Limits

General requirements for handling storage containers:

1. They must be in good condition.
2. Replace leaking containers.
3. Keep containers closed.
4. The containers must be compatible with the hazardous waste stored in them, and must meet DOT standards.
5. Do not mix wastes.
6. Provide adequate aisle space for easy access and visibility.
7. Containers must be inspected at least weekly to check for leaks and signs of corrosion.

As a small quantity generator, you are allowed to store on-site up to 6,000 kg (13,200 lb.) of hazardous waste for a period of 180 days.

Step 6:Transport and Dispose of Waste Properly

A generator is forever responsible for his or her hazardous waste. To reduce your liability and to ensure the waste is transported and properly disposed, choose a transporter that has met the following requirements:

1. Obtained an EPA/DEP I.D. number;
2. Use manifests;
3. Ablity to clean up hazardous waste discharges during transportation-related incidents;
4. Documentation of financial liability.

Transporters storing more than 24 hours at a transfer facility must notify the DEP and meet many TSD requirements, including containment, contingency plan, training, security and closure.

Step 7:Manifests and Transport of Hazardous Waste

The Uniform Hazardous Waste Manifest is a multi-copy shipping document that must accompany hazardous waste shipments. The State of Florida requires the use of this manifest when disposing of hazardous waste.

Step 8:Emergency Procedures Plan

1. Designate an emergency coordinator;
2. Post emergency information by the phone; and,
3. Provide and document adequate training for personnel handling hazardous waste.

Step 9:Preparedness and Prevention Plan

If you accumulate hazardous waste on-site, you are required to prepare a Preparedness and Prevention Plan.

1. Maintain a safe work place;
2. Accessible telephones;
3. Maintain fire extinguishers and spill control equipment;
4. Maintain aisle space in work area;
5. Notify police, fire department, and state emergency response teams of the types of wastes handled at your facility.

Step 10: Keep Records

Maintain these records for a minimum of three years:

1. Manifests;
2. Land Disposal Restriction (LDR) Forms;
3. Manifest exception reports;
4. Analytical and other reports;
5. Training documents;
6. Inspection logs; and,
7. Correspondence.

For additional information on the Small Quantity Generator requirements call or write for:

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Waste Management Section
2600 Blair Stone Road Tallahassee, Florida 32399-2400
Phone: (850) 488-0300
www.dep.state.fl.us

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4.3.1.3 Leachable Metal Content

The SPLP test was performed on all samples collected to assess the potential impact of the waste on groundwater. Table 4-13 lists the leachable metal content of the ABM samples for the SPLP test.

Table 4-13. 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

[1] Calculated by using ½ the detection limit for undetected samples

[2] Analysis on composite sample from each site

4.3.2 Discussion

4.3.2.1 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 resulted in calculations below the TCLP limits for the eight heavy metals listed in 40 CFR 261. These results show that the samples collected were not hazardous for the toxicity characteristic.

4.3.2.2 Direct Human Exposure

The total metal concentrations of the general contractor waste ABM samples were compared to the Florida Soil Cleanup Target Levels. As discussed previously, these goals are tools for assessing the risk of a soil or soil-like material in the enviroment. None of the samples exceeded the residential or industrial limits of the Florida Soil Cleanup Goals.

None of the samples exceeded the residential or industrial limits of the Florida SCTLs. Theses 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. Table 4-14 summarizes the total metal results data.

Table 4-14. Summary Total Metal Limits and Comparative Results.

	As	Cd	Cr	Cu	Fe	Pb	Ni	Se	Zn
Res. SCG (mg/kg)	0.8	75	290	105	23,000	500	105	390	23,000
Ind. SCG (mg/kg)	3.7	1300	430	12,000	490,000	920	28,000	9,100	560,000
No. Res.	0	0	0	0	0	0	0	0	0
No. Ind.	0	0	0	0	0	0	0	0	0

4.3.2.3 Risk to Groundwater

The drinking water standards adopted 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 appeared normally distributed and therefore the arithmetic mean would likely be used.

Table 4-15. Summary of Leaching Limits and Comparative Results.

	As	Cd	Cr	Cu	Fe	Pb	Ni	Se	Zn
GWGC (mg/L)	.05	.005	0.1	1.0	0.3	0.015	0.1	.05	5.0
No. above GWGC (out of 15)	0*	1	0	0	7	0	0	0*	0

*Out of 3

4.3.2.4 Correlation of Data

A correlation of total metal amounts and leachability was performed on the individual samples above the detection limits. There was little correlation observed 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%.

4.3.2.5 Implication for Management

Sandblasting contractor waste was non-hazardous for the sites characterized in this study. The sites sampled for this research blasted various equipments from scaffolding to heavy machinery. The concentration of heavy metals in the sandblast grit did not pose direct threat to human health when compared to state and risk-based standards. This waste could be land applied if it would not potentially contaminate the ground water at the site. Table 4-16 summarizes the main concerns with sandblasting contractor waste ABM.

Table 4-16. Potential Concerns with Sandblasting Contractor Waste ABM

Metal	Direct Exposure Residential	Direct Exposure Industrial	Groundwater-Leaching
Arsenic	No	No	No
Cadmium	No	No	Possibly
Chromium	No	No	No
Copper	No	No	No
Iron	No	No	Yes
Lead	No	No	No
Nickel	No	No	No
Selenium	No	No	No
Zinc	No	No	Yes

SPLP results that exceed a GWGC standard would require generators to dispose of this waste in lined landfills. For the case of general contractor waste ABM, with the exception of one sample for cadmium, only secondary standards were violated (iron and zinc). The applicability of secondary standards to the leaching of wastes has not been fully explored. Local regulatory officials should be consulted when considering management options for waste that may leach secondary standard compounds. As a conservative management practice, waste ABM should be stored in a manner to minimize leachate production. Disposing of spent silica sand ABM on-site, a relatively common practice does not likely present a direct exposure risk, but may present a risk to groundwater from leaching of secondary standards. Recycling, or disposal in unlined landfills, should be considered as more acceptable management options.0

4.4 RESULTS AND DISCUSSION OF LYSIMETER EXPERIMENT

4.4.1 Results

A number of analyses were conducted 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.

4.4.1.1 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 4-17 through 4-19 are a summary of each lysimeter batch characteristics including total metal concentration, TCLP and SPLP leaching.

The total metals discovered in the lysimeter samples were 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, indicated that some of the metals (As, Cr, Ni) were inherent to the media and other metals (Cu, Zn, Pb) came from the blasting residuals. The sandblasting contractor samples (Lysimeters 3 and 5) were similar, except lysimeter 3 had more iron and lysimeter 5 had more zinc. The unused silica sand media contained no metals above detection limits except for a small amount of mercury and some iron.

Table 4-17. 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

The leaching concentrations of the samples varied, indicating that complex leaching mechanisms are involved in the batch processes. Lysimeters 1 and 2 duplicated 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.

Table 4-18. 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 4-19. **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

4.4.1.2 Lysimeter Leachate Analyses

The first characteristics of interest for the lysimeters were the general parameters. These parameters can provide some idea of what kind of processes are occurring inside the lysimeters and the types of conditions the waste was exposed to.

4.4.1.2.1 General Water Quality Parameters

Table 4-20 contains the number of readings, the ranges observed, and the averages for many general water quality parameters. Some of the parameters (pH, Conductivity, and NPOC) expressed trends that will be examined further. pH is an important parameter that can affect the leachability of many substances as well as metal speciation. Figure 4-13 is the plot of pH for the lysimeters. The pH curves reflected the degree of buffering capacity of the waste. Buffer capacity is the ability of a substance to resist pH change with the addition of a strong acid or base. Carbonate species were believed to be responsible for the majority of the buffering capacity.

The primary buffer encountered in waste materials and soil is carbonate alkalinity. pH buffers include metal ions, oxidation reduction potential buffers (Snoeyink and Jenkins). 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 a small amount of buffering capacity and was expressed late in the test. As expected, the SPLP fluid did not change pH in the control lysimeter.

The dissolved oxygen (DO) level may indicate whether biological reactions occur in the lysimeters. From the Table 4-20 DO data, Lysimeter 3 was the only lysimeter with some potential biological activity. This data is confirmed by the nonpurgeable organic carbon data. There was little organic carbon in these lysimeters except for lysimeter 3. The graph of the nonpurgeable organic carbon follows a typical leaching curve for lysimeter 3 (Figure 4-14).

Table 4-20. General Water Quality 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 $CaCO_3$

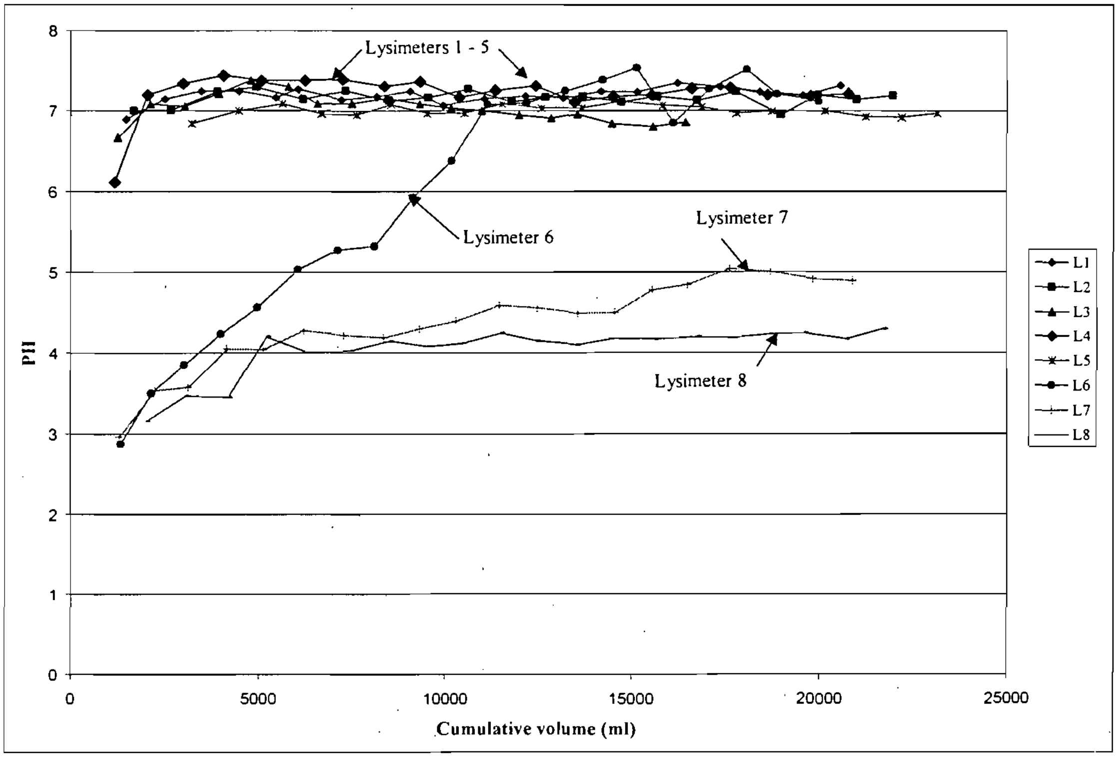

Figure 4-13. Lysimeter pH graph.

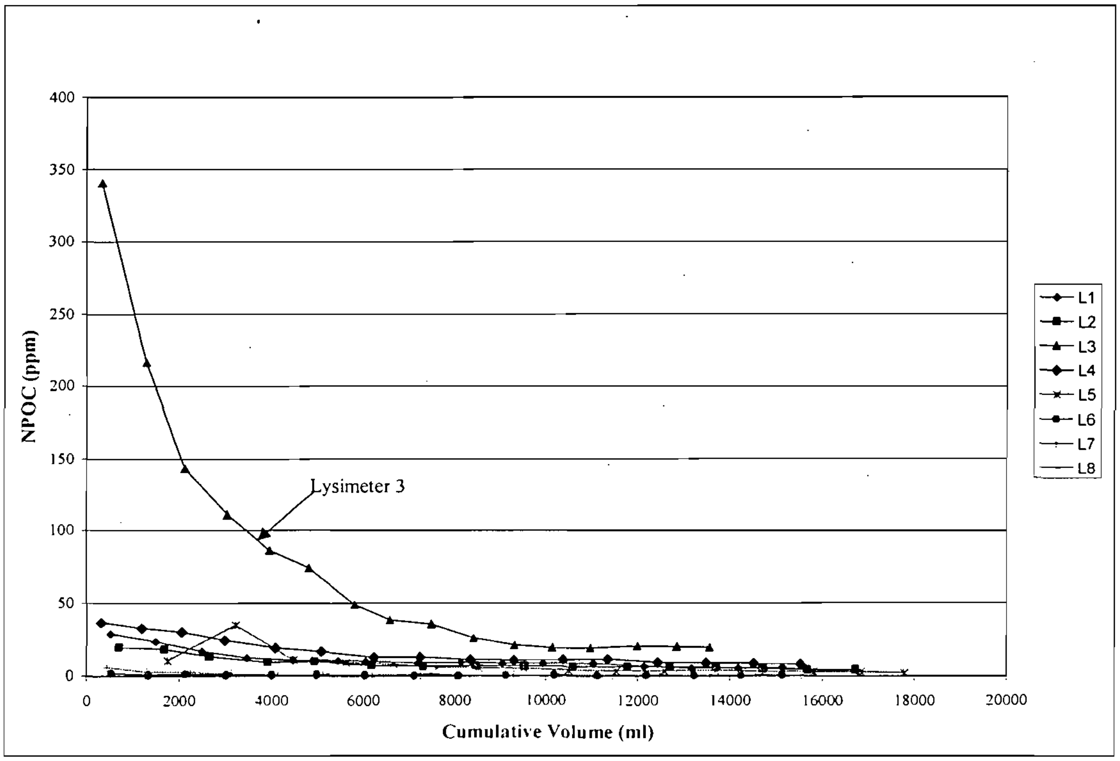

Figure 4-14. Nonpurgeable Organic Carbon

Conductivity and TDS are related. The more total dissolved solids, the more ions available to produce conductance. Table 4-20 shows some relationship between them, and this was further investigated. The ions contribute to the TDS and conductivity and Table 4-21 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 4-22 is a "solids balance" for the total amount of ions leached and the total TDS leached for each lysimeter. The sums matched up relatively well in most cases, with all ion sums slightly lower. Differences may be explained by organic matter (Lys 3) and other non-detected ions. Figure 4-15 presents the leaching curve for conductivity. TDS and the inorganic ions followed this same trend.

Table 4-21. 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 4-22. 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**

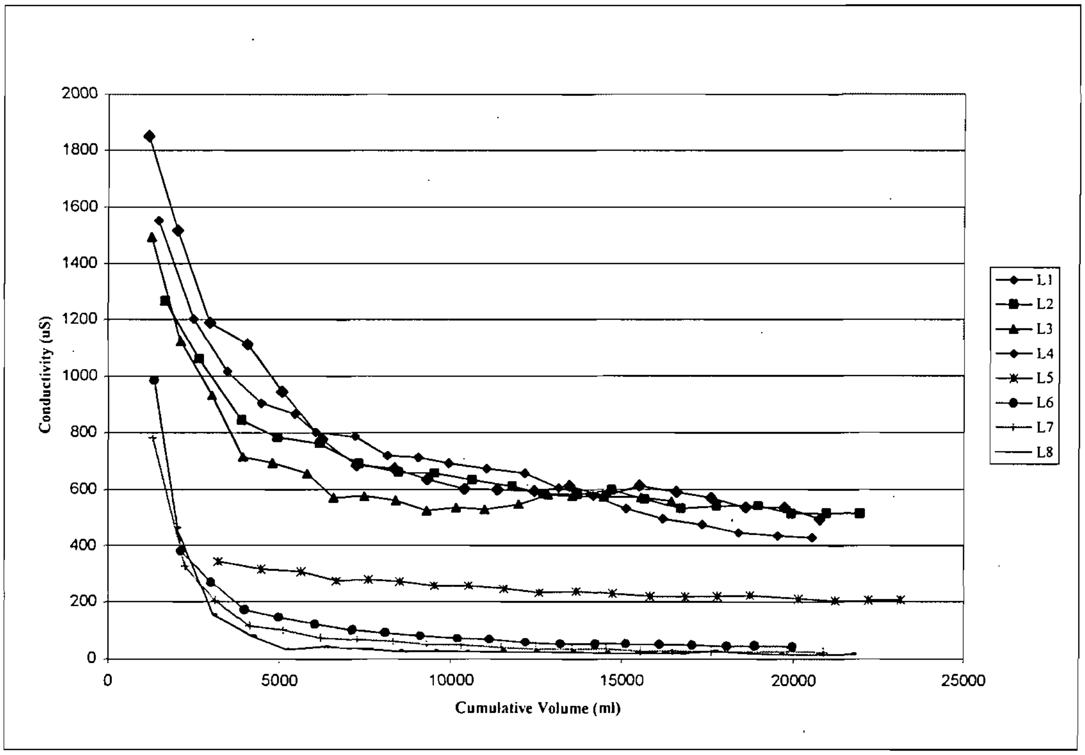

Figure 4-15. Conductivity

4.4.1.2.2 Heavy Metals

Many of the general water quality 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 similar leaching curves were formed by the leaching of heavy metals from this waste stream. Metal samples were collected 10 times (except lysimeter 3, 8 times) during the 6 week study. Table 4-23 presents the number of detected samples out of 10 (8 for L3) for each metal.

Table 4-23. Heavy Metals found in Lysimeter Leachate (mg/L).

	L1	L2	L3	L4	L5	L6	L7	L8
No. Detected	0	0	2	0	7	0	0	0
Max Cadmium	N/A	N/A	.011	N/A	.004	N/A	N/A	N/A
Min Cadmium	N/A	N/A	<.001	N/A	<.001	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 4-16 through 4-19 present the leaching curves for these metals from their respective lysimeters.

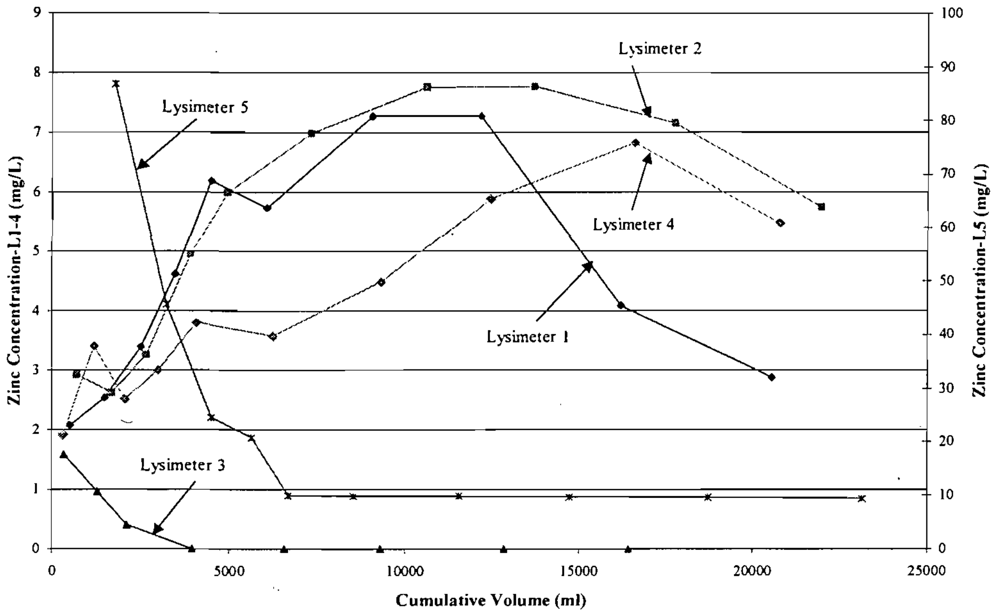

Figure 4-16. Zinc Leaching from Lysimeters.

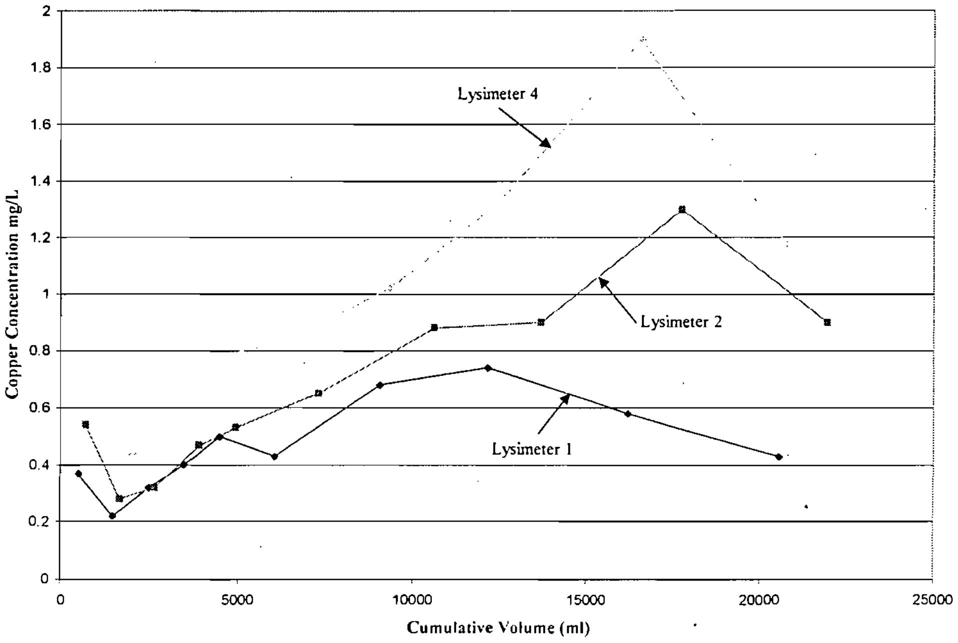

Figure 4-17. Copper Leaching from Lysimeters.

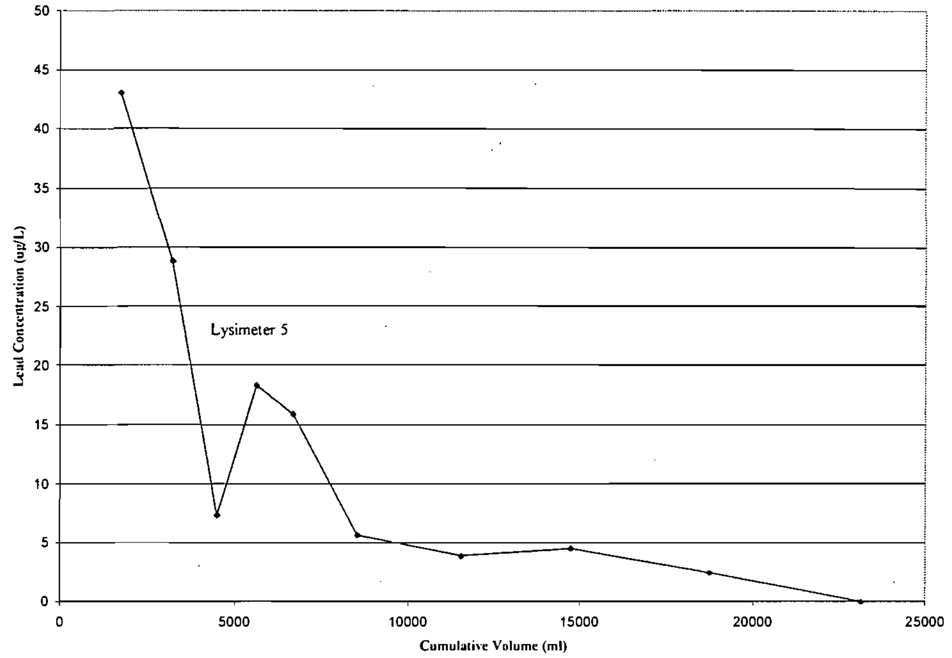

Figure 4-18. Lead Leaching from Lysimeter 5.

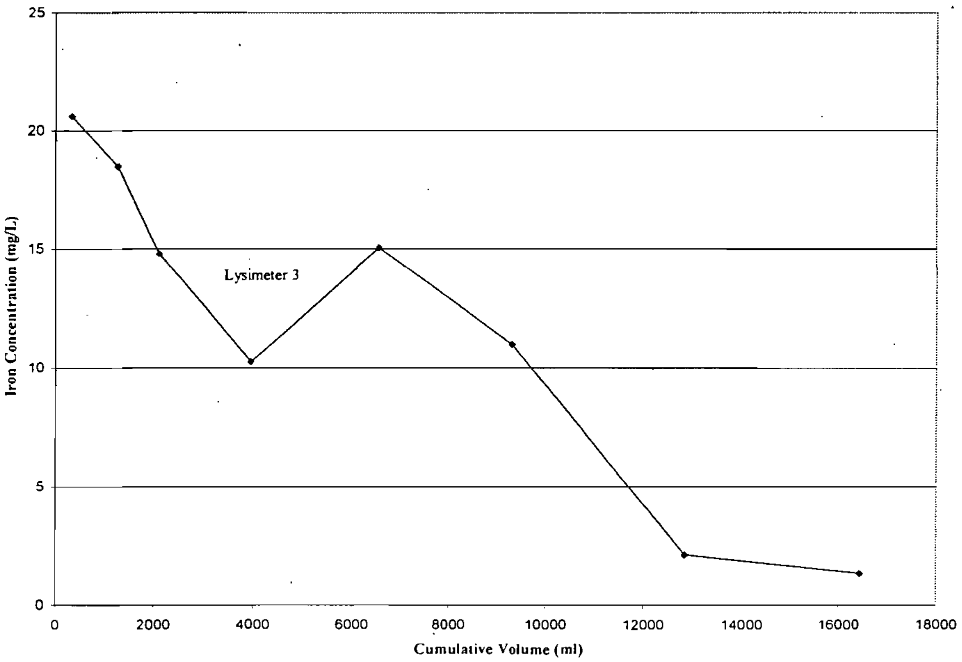

Figure 4-19. Iron Leaching from Lysimeter 3.

4.4.2 Discussion

4.4.2.1 Leaching Relationships

Many of the general water quality parameters and all of the ions demonstrated similar leaching relationships over time, starting at a maximum value then decreasing to steady state. One reason for this phenomenon is that the readily leachable concentrations in the waste stream are high to begin with and then as constituents get washed away, the amount that can be leachable falls to a steady state. Leaching mechanisms may be very complex and are affected by physical waste characteristics (e.g. particle size, porosity) and chemical characteristics of the leaching fluid (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 a larger 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).

In general, 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 travel 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 in that manner.

4.4.2.2 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 were 0.89, 0.93, and 0.82 respectively (Figures 4-20 through 4-22). Samples which leached, but were below the total metal detection limit, were assumed half of the limit (for copper and lead only).

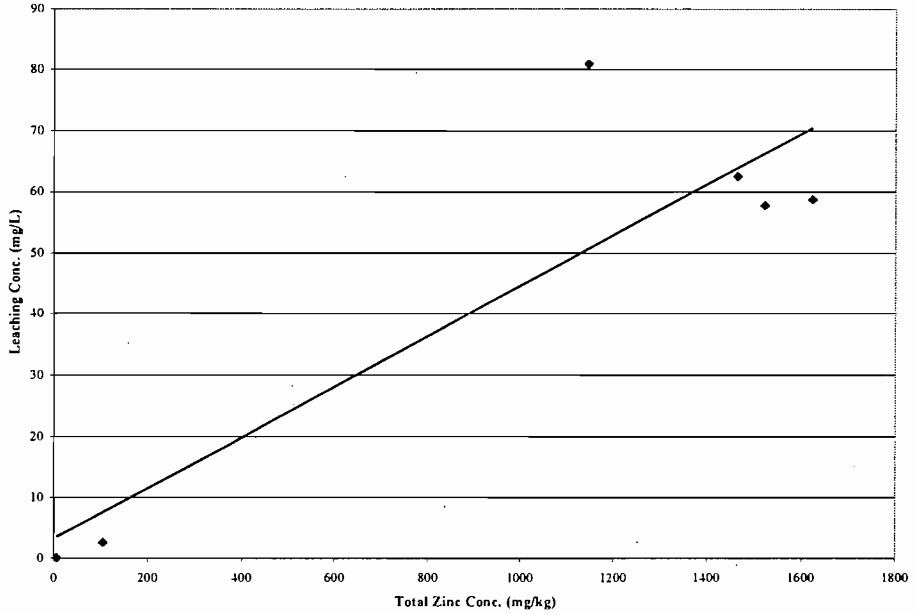

Figure 4-20. Zinc TCLP and Total Metal Correlation.

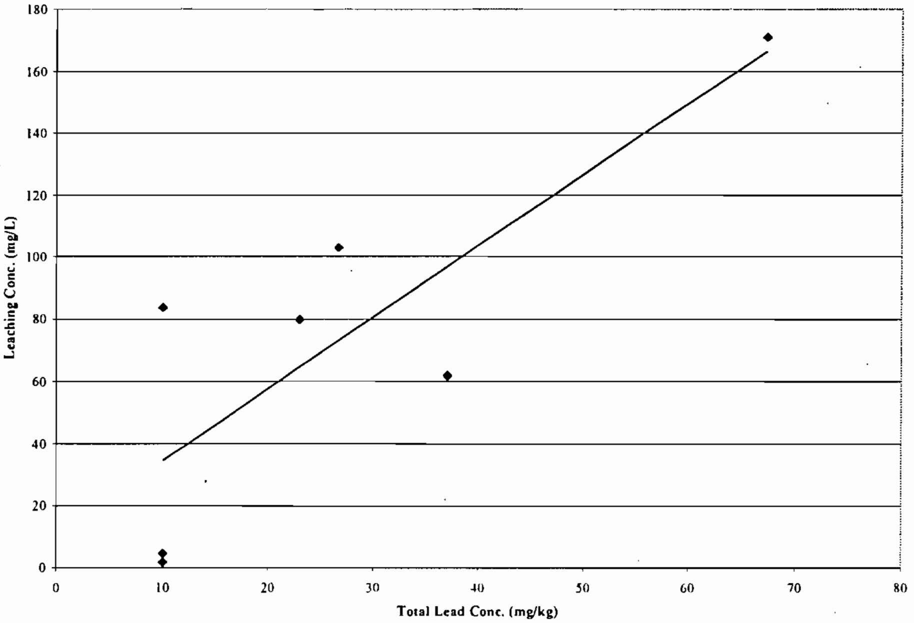

Figure 4-21. Copper TCLP and Total Metal Correlation.

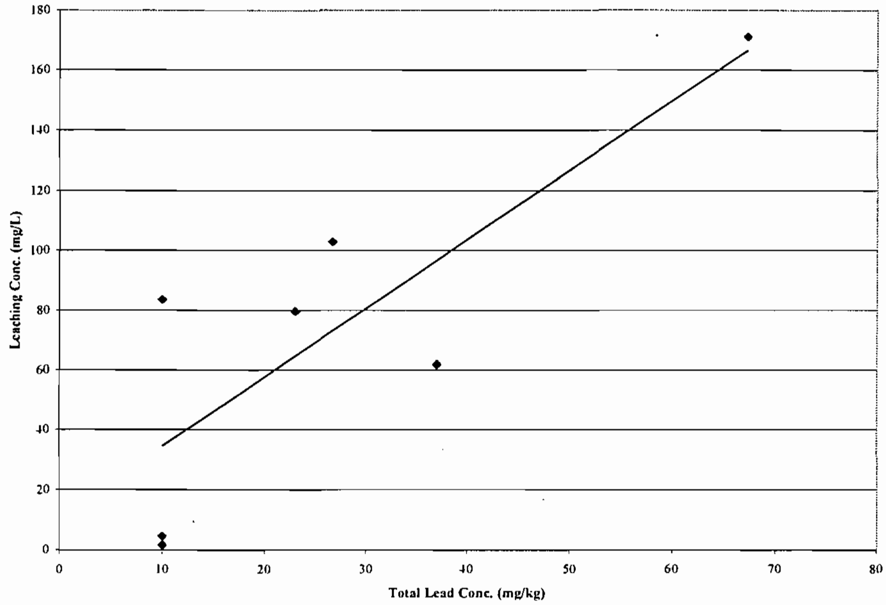

Figure 4-22. Lead TCLP and Total Metal Correlation.

A percentage of the total metals leached during the TCLP, SPLP, and lysimeter tests. Tables 4-24 through 4-26 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 4-23 illustrates this relationship with a 0.80 correlation coefficient.

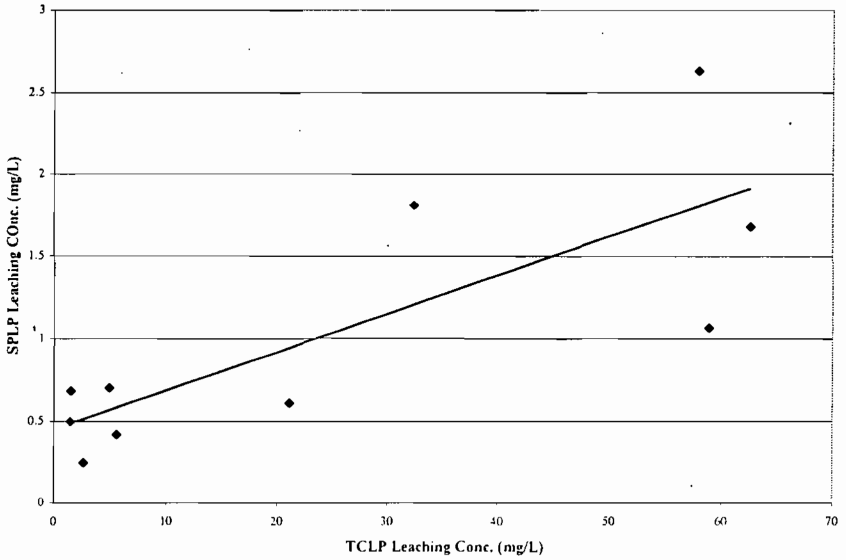

Figure 4-23. TCLP and SPLP Correlation

Table 4-24. 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 4-25. 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 4-26. 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%

4.4.2.3 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 occurring inside 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 1997). 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 providing some degree of dilution of the leachate as might occur in the environment (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 assess the impact of this waste stream on the natural environment.

The concentrations of some of the heavy metals exceeded groundwater guidance concentrations in lysimeters. This included some cases where the GWGCs were not exceeded in the SPLP tests. A complete examination of the lysimeter data and their relationship with the batch SPLP data was beyond the scope of this report. For additional information and discussion, see the Master of Engineering thesis by Carlson (1998). Additional analyses and examination will be performed as part of technical journal articles that will be drafted and submitted in the future.

5. BEST MANAGEMENT PRACTICES

In addition to the analytical work presented as part of this research, a document with best management practices for the management of ABM waste was produced. As mentioned in Chapter 2, this document was designed to provide generators, regulators, and suppliers in the industry with the needed information to manage waste ABM appropriately. The management practices presented covers management from generation, waste reduction, reuse, recycling, and disposal. An overview of management options is presented in Figure 5-1.

A draft of the best management practices was presented to the Technical Advisory Group consisting of industry professionals, regulators, and engineers, on January 30, 1998. Comments were accepted on the document through March, and changes were made.

The BMP document is simply organized and addresses such situations as when waste ABM is hazardous and how it should be handled, where non-hazardous waste ABM can be disposed, whether or not the waste may be land applied, and how to reduce overall amounts of waste ABM. The document also includes all of the pertinent state standards, goals and regulations that may apply to waste ABM. The analytical tests appropriate for waste ABM are outlined and explained in the BMP document. Table 5-1 summarizes the content of the BMP document. The document is presented in Appendix C.

5.1 IMPLEMENTATION OF BMP'S

Table 5-1. Topics in BMP Document

Topic
Is my waste ABM hazardous?
What kind of hazardous waste generator am I?
What are my requirements as a hazardous waste generator?
What if my waste ABM is not hazardous?
Where can I dispose of my nonhazardous ABM?
What tests do I need to run on my waste ABM?
How can I reduce the amount of ABM waste I produce?
How can I recycle my waste ABM?
Who should I contact if I have questions about my waste ABM?

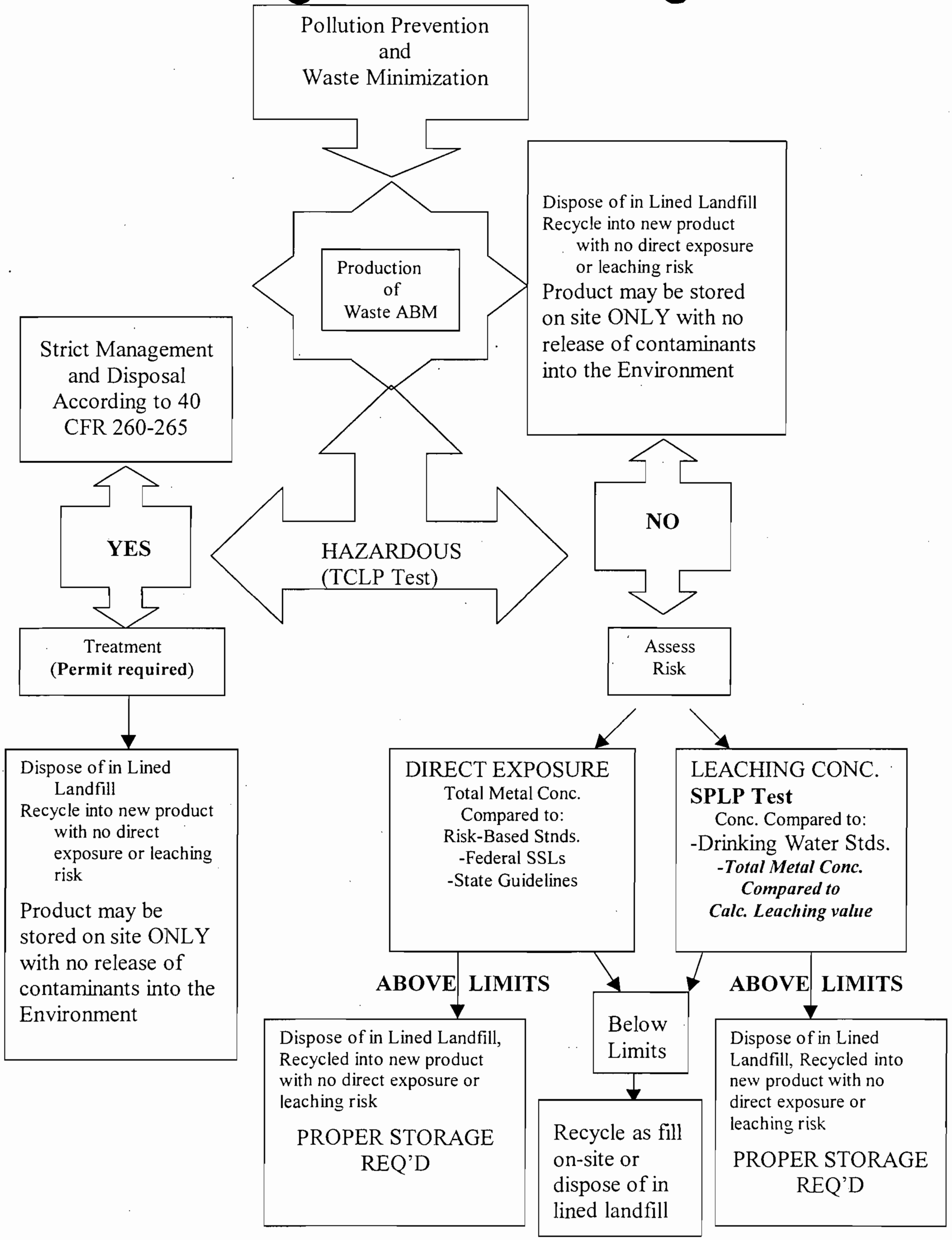

Figure 5-1. Overview of Management Options

6. CONCLUSIONS

The process of abrasive blasting creates a solid waste stream composed of the media utilized for blasting and the materials removed by the process. These materials are typically paints and coatings that serve as protection for the surfaces blasted. Coatings and paint contain pigments and other additives like anti-corrosion agents and biocides that may contain heavy metal compounds. These metallic compounds end up in the abrasive blasting waste stream potentially causing harm to human health and the environment.

Typical generators of abrasive blasting media waste are the military, departments of transportation, ship maintenance facilities and sandblasting contractors. The military and transportation departments have organized management practices that are followed for the solid waste created by abrasive blasting. Ship maintenance facilities and sandblasting contractors may be smaller operations, and are often uncertain of the best way to manage ABM waste. An overall, consistent management practice would benefit the smaller industries and the agencies that regulate them.

This research developed a management strategy outlining the steps that can be taken by a generator to properly manage waste ABM. Th research studied several types of waste ABM, but concentrated on ship maintenance facility and sandblasting contractor waste. The abrasive blasting media encountered during this research was typically non-hazardous. The FDEP file reviews also confirm this, although when paints with known heavy metal contents are blasted (such as lead-based paint), the waste can easily take on the hazardous characteristic for toxicity.

When waste ABM is non-hazardous, other considerations must be made to assess the safety of human health and the environment for various management options. Direct exposure risk through ingestion, inhalation and dermal contact must be considered. Direct exposure limits are typically risk-based concentrations utilized by regulators in assessing the contamination of soil at a site or to regulate the placing of materials on the land. If waste ABM may possibly be placed on the land or allowed to accumulate on site, the direct exposure risk must be assessed. For the coal slag media typically used to blast ships, the concentration of arsenic typically exceeds direct exposure limits for residential areas, and occasionally industrial areas. The sandblasting contractor waste examined for this study was not found to exceed any direct exposure limits.

The leachability of waste ABM must be considered in terms of potential groundwater contamination. The SPLP test is an assay used to simulate rainfall conditions and examine the leachability of a waste. Lysimeter studies were also completed to further examine these leaching characteristics. For the ship maintenance facilities, iron, copper, and zinc exceeded their respective groundwater guidance concentrations at times. One sample exceeded the standard for lead. Iron also leached above the limits for the sandblasting contractor media. One sample of the contractor media leached above the standard for cadmium.

Because this waste stream does exceed some groundwater guidance concentrations, the production of leachate must be minimized. The best way to minimize leachate production is to not produce it at all in the first place. Leachate production may be prevented by covering the waste with a plastic cover or by keeping it under a roof or overhang. Because direct exposure limits may also occasionally be exceeded, storage on an impervious surface, like concrete is recommended. Waste ABM may be disposed of in a lined landfill or recycled in a manner which will not produce leachate when the waste exceeds groundwater guidance concentrations. An excellent recycling option for the coals slag used media is at a cement kiln. The media contains minerals needed as feedstock in the cement-making process. Other recycling options include as aggregate in concrete or asphalt.

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APPENDIX A

QA/QC Data

Table A-1 is a summary of the recoveries from the spikes used as quality assurance and control for the analyses completed. The blank spikes were spiked deionized water samples treated the same way as samples during laboratory procedures. Blanks samples of deionized water were also incorporated to make sure no contamination occurred in the lab. Matrix spikes were samples spiked with a known concentration. Duplicates in the field and in the lab were analyzed to check for consistency of the samples. The raw data including spikes and duplicates follows in table A-1 through A-6.

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%
Chromium	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

Table A-2. Data for Total Metal-Flame

TOTAL	METALS	Sample wt.	Lead	Copper	Chromium	Zinc	Cadmium	Nickel	Iron
SAMPLE ID		g	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg
MSBLANK	Blank Spike (mg/L)	-	4.5	4.7	5.2	4.6	2.3	5.0	2.7
SBA1		2.20	78.6	3579.5	50.9	2738.6	<2.5	72.3	50454.5
SBA1MS	Matrix Spike	2.11	273.0	-	226.5	-	105.7	294.8	
SBA1MSD	Matrix Spike - Dup	2.27	259.0	-	196.5	-	101.3	261.2	
SBA2		2.40	39.6	183.3	52.1	2102.1	<2.5	62.1	46166.7
SBA2D	Field Dup	2.04	40.7	211.8	48.5	1781.9	<2.5	54.4	49166.7
SBA3		2.12	44.8	448.6	125.0	3344.3	<2.5	71.7	51509.4
SBA4		2.23	25.6	326.9	73.1	373.9	<2.5	41.7	44529.1
SBA4D	Field Dup	2.01	26.4	62.2	93.0	119.7	<2.5	46.8	51865.7
SBA5		2.08	40.9	1086.5	99.5	1870.2	<2.5	55.3	49326.9
SBA6		2.40	183.8	1500.0	104.2	2297.9	<2.5	100.8	109479.2
SBB1		2.02	67.3	2607.4	93.6	3071.8	<2.5	53.0	44594.1
SBB2		2.37	216.5	192.0	126.2	215.7	<2.5	55.7	42995.8
SBB2D	Method Dup	2.04	194.1	307.8	135.3	306.9	<2.5	63.7	49313.7
SBB3		2.38	102.5	697.5	111.3	558.8	<2.5	57.6	46512.6
SBB4		2.10	140.0	709.5	103.8	390.0	<2.5	56.2	49428.6
SBB5		2.36	55.1	4131.4	114.0	4447.0	<2.5	58.5	42881.4
SBB6		2.20	105.9	954.5	92.3	4231.8	<2.5	64.5	45313.6
SBC1		2.06	78.2	728.2	45.6	997.6	<2.5	51.9	48291.3
SBC2		2.02	60.9	1361.4	47.0	2787.1	<2.5	61.9	56980.2
SBC3		1.94	446.4	184.0	95.9	2054.1	<2.5	50.5	54948.5
SBC4		2.09	77.5	1411.5	54.5	1105.3	<2.5	48.3	52392.3
SBC5		2.01	93.5	626.9	69.2	916.7	<2.5	68.2	88432.8
SBC6		2.19	87.7	474.0	39.7	588.1	<2.5	42.9	45547.9
SBC7		2.05	38.0	365.9	42.4	8885.4	<2.5	67.8	53073.2
SBC8		2.00	40.5	516.5	47.0	2085.0	<2.5	59.0	89712.5
GCA1		2.05	<25	<25	44.9	4328.0	<2.5	9.3	2801.0
GCA2		2.13	<25	<25	31.0	484.7	<2.5	12.7	1379.3
GCA3		2.07	81.2	<25	33.3	1678.7	<2.5	7.7	1527.5
GCA4		2.46	<25	<25	12.6	329.1	<2.5	7.3	882.1
GCA5		2.07	<25	<25	26.1	1386.5	<2.5	12.6	903.9
GCA6		2.28	<25	<25	17.1	1290.6	<2.5	5.7	826.8
GCB1		2.09	99.5	<25	45.5	102.8	<2.5	4.8	875.1
GCB2		2.34	71.8	<25	37.2	99.6	<2.5	9.4	939.3
GCB3		2.01	44.3	<25	17.4	100.1	<2.5	7.0	1595.0
GCB4		2.51	54.6	<25	41.0	92.1	<2.5	7.6	1072.9
BLANK		-	BDL	BDL	BDL	BDL	BDL	BDL	BDL
GCC1		2.13	58.7	<25	32.9	24.3	<2.5	22.1	1626.8
GCC2		1.60	43.8	<25	53.8	26.1	<2.5	53.1	1813.8
GCC3		1.98	82.3	<25	59.1	30.9	<2.5	49.5	1744.9
GCC4		1.75	57.7	<25	38.9	29.6	<2.5	27.4	1474.9
GCC5		1.56	53.2	<25	43.6	65.4	<2.5	35.9	1233.3

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
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UNIVERSITY OF FLORIDA

1998

This thesis is dedicated to my husband, Brian John Carlson.

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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.

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 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.

of [illegible]

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.

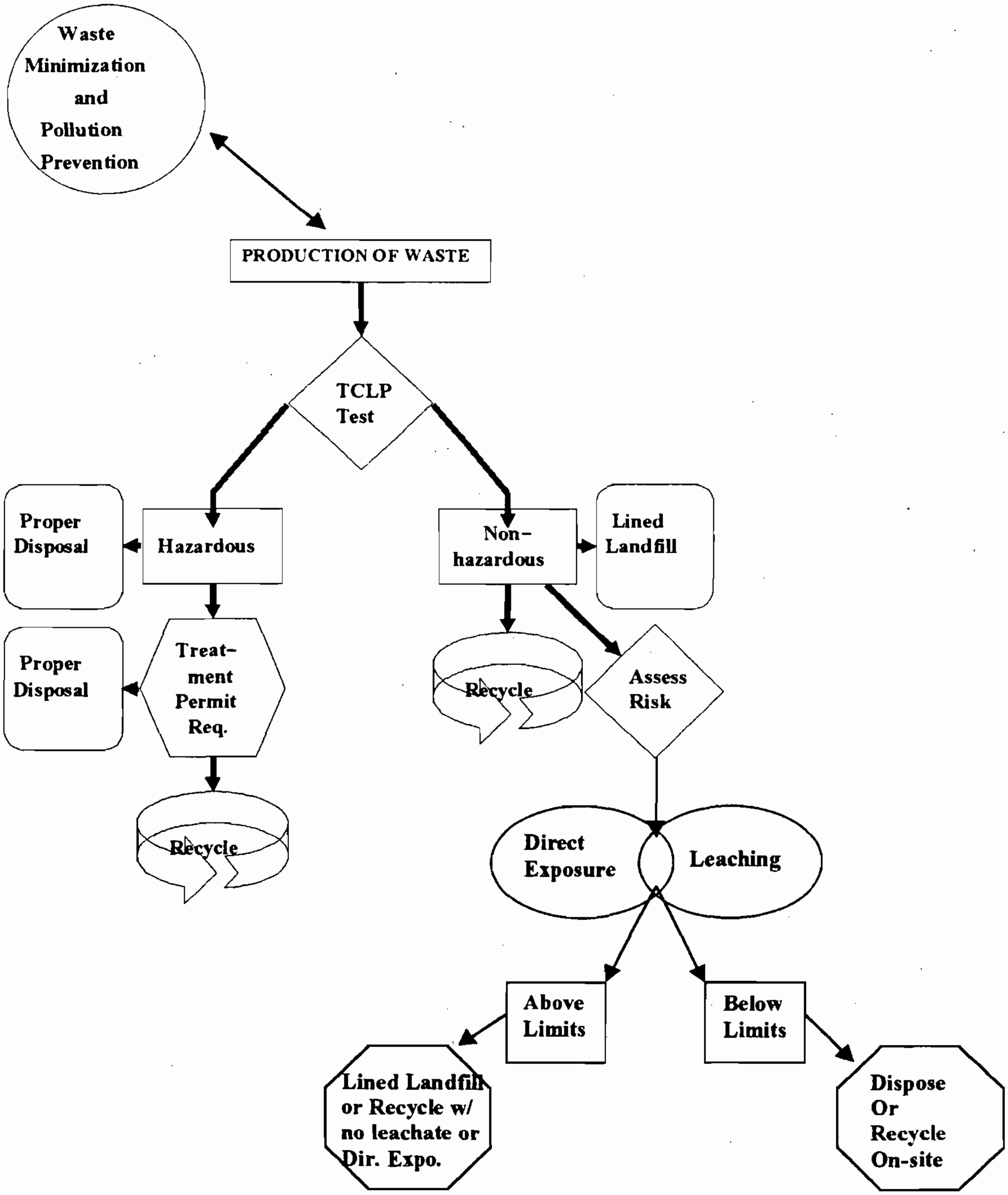

Figure 1-1. Management Flow Chart for ABM waste

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.

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 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 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~~ 9,100
Zn	-	5,000	23,000	12,000	23,000	560,000

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	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Industrial	3.7	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Leaching	29	8	38	—	—	—	130	[illegible]	[illegible]

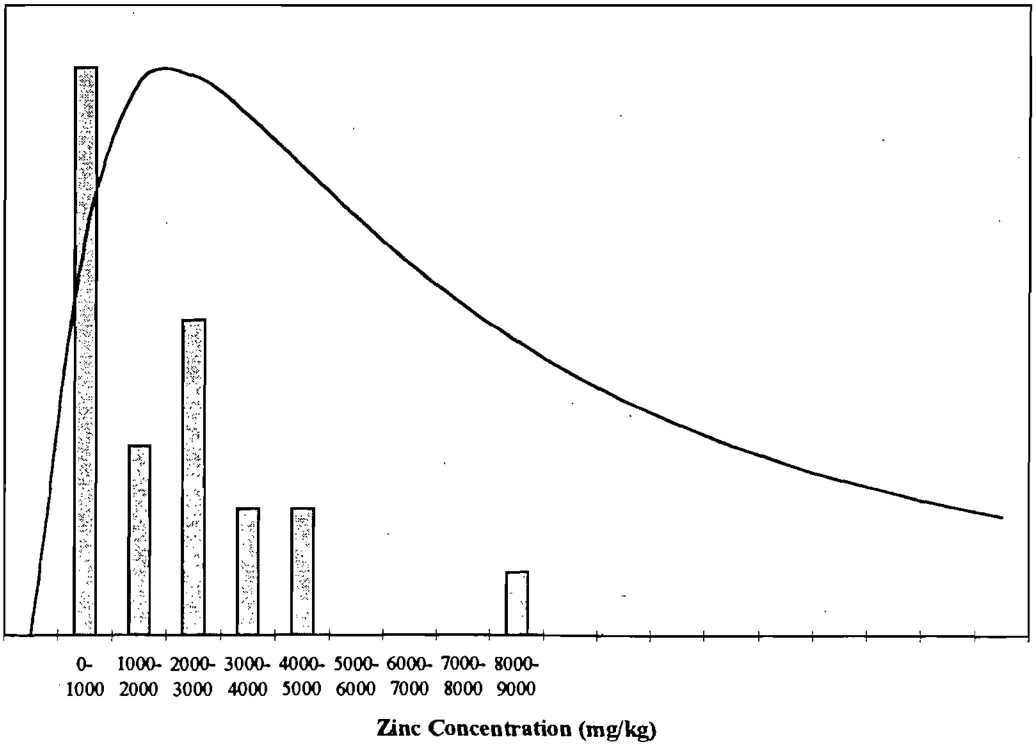

Figure 2-2. Zinc Histogram and Lognormal Distribution

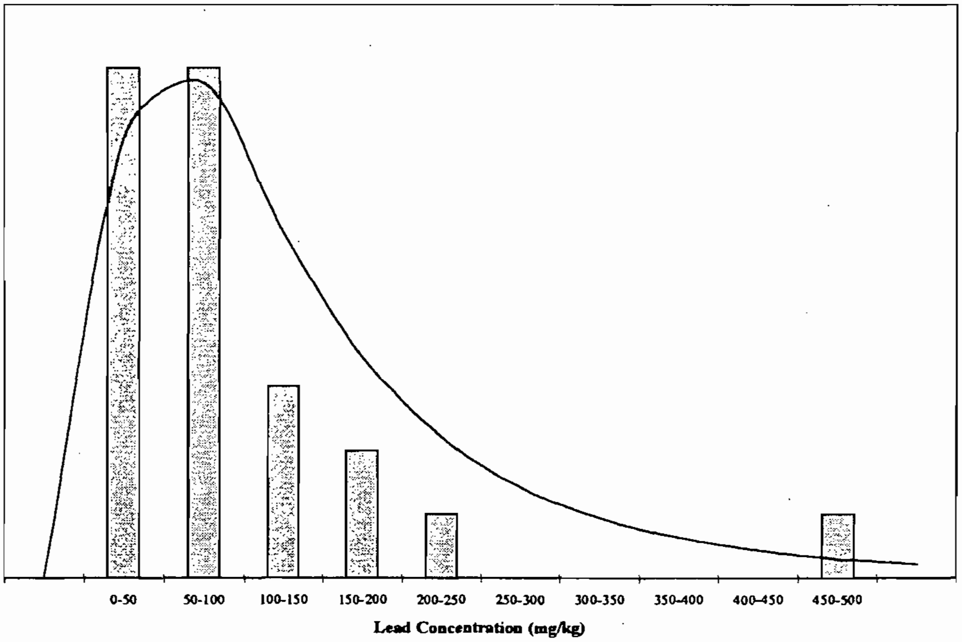

Figure 2-3. Lead Histogram and Lognormal Distribution.

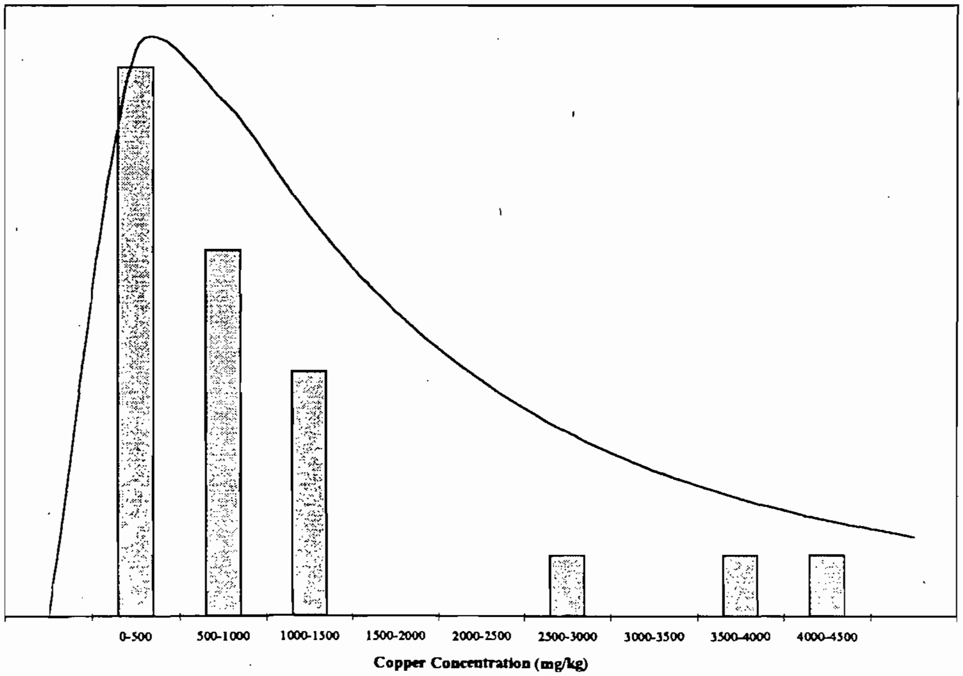

Figure 2-4. Copper Histogram and Lognormal Distribution.

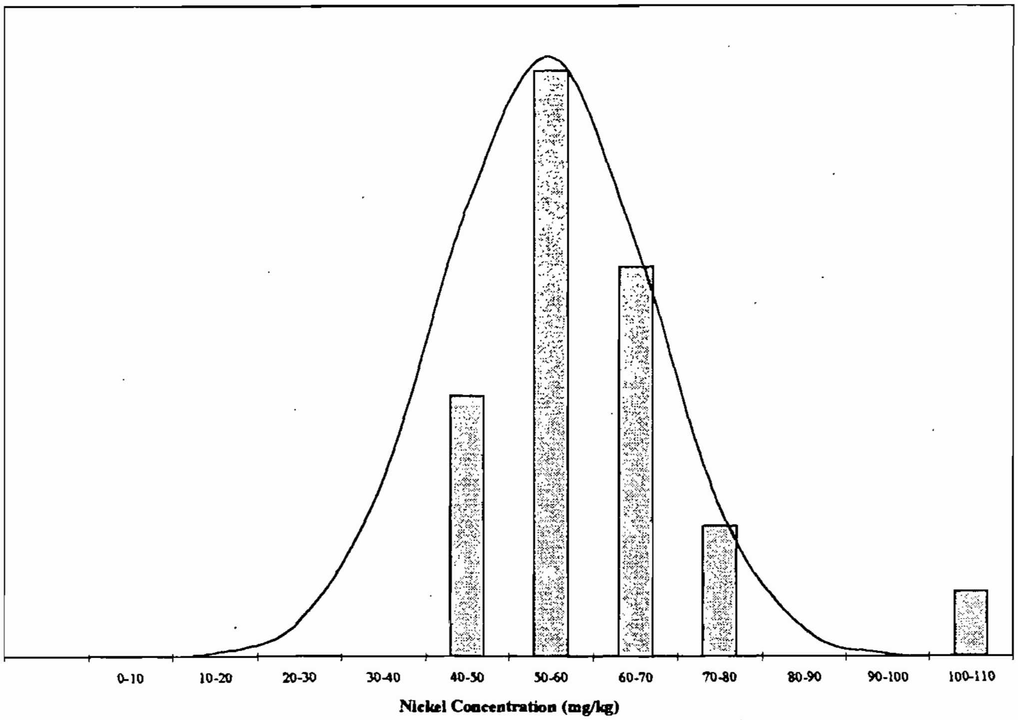

Figure 2-5. Nickel Histogram and Lognormal Distribution.

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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.

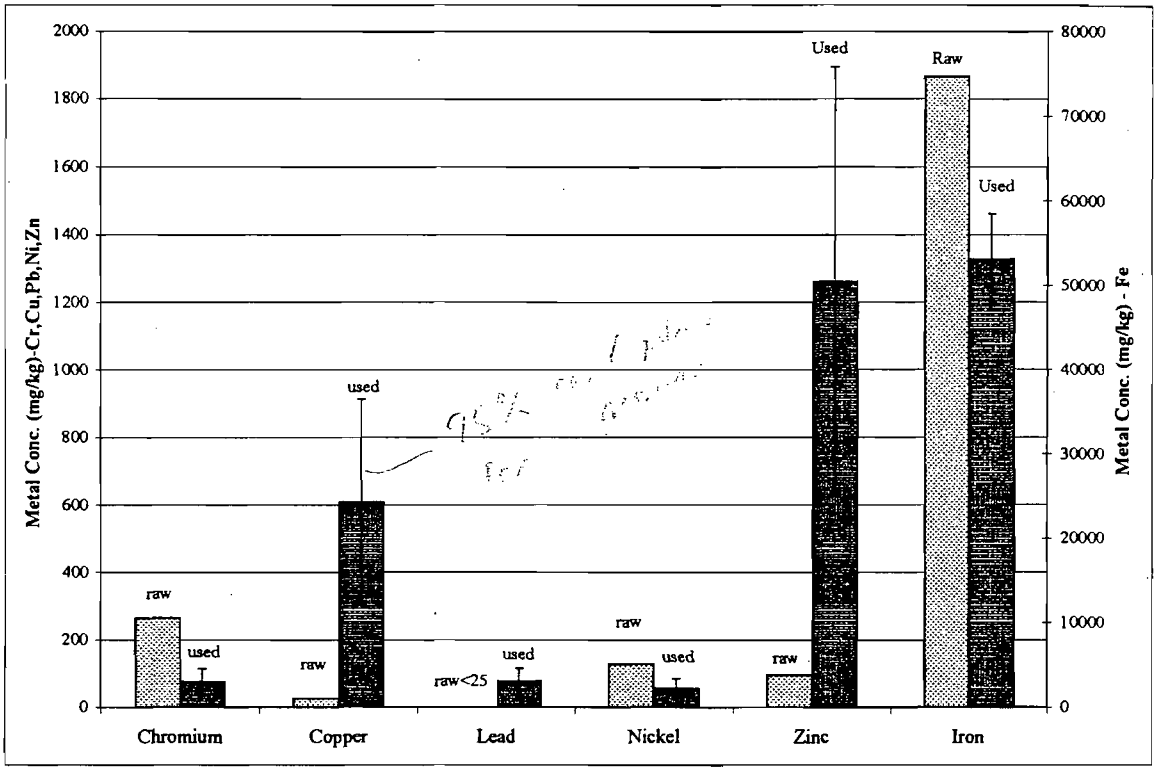

Figure 2-6. Comparison of Raw and Used Media

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.

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.

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

[1] Average calculated by using ½ the detection limit for undetected samples

[2] Analysis on composite sample from each site

0.005 0.1 0.015 0.1

1.0 0.3 5.0

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.

do you have a table showing total analys[illegible] 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 lim

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 [illegible]

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%

Correlation of Data

typo

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%.

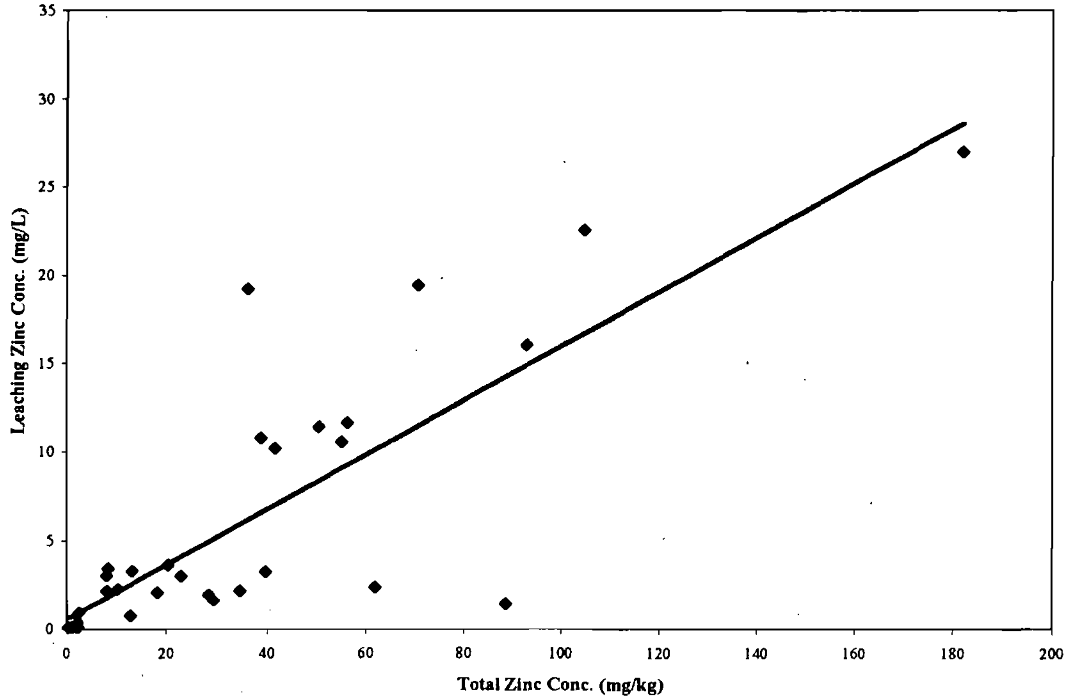

Figure 2-7. Correlation of Leachable and Total Metals for Zinc

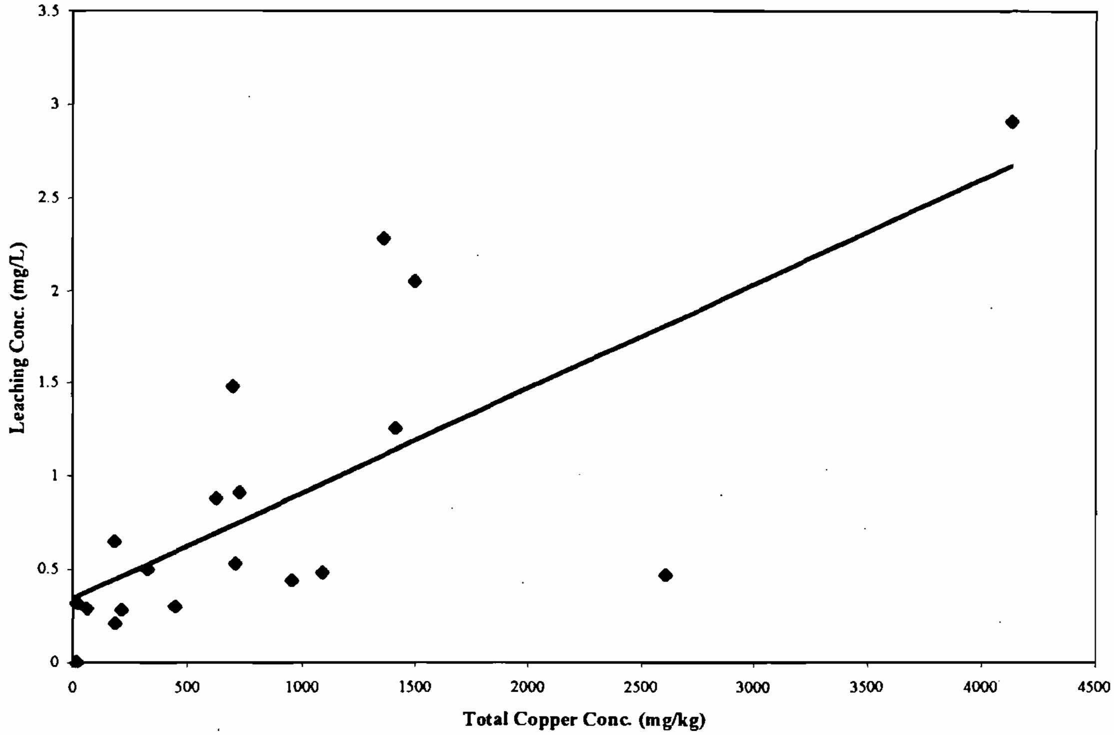

Figure 2-8. Correlation of Leaching and Total Metals for Copper

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).

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.

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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.

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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

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Chap. 2
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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 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.

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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~~, for both a residential and an industrial setting

(risk-based contaminant guidelines

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See correction
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.

Soil: Residential [illegible] 75 210 110 23,000 400 [illegible] 390 23,000
Industrial [illegible] 1300 [illegible] 76,000 [illegible] [illegible] [illegible] [illegible] 560,000
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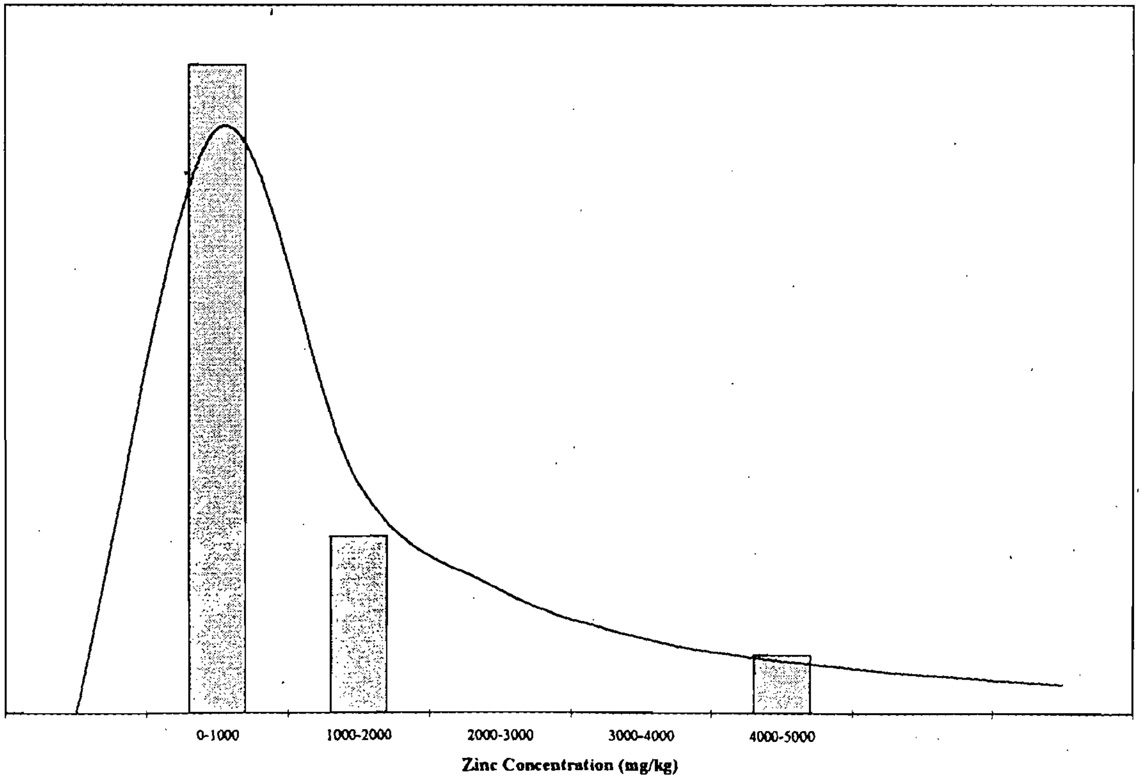

Figure 3-2. Zinc Histogram and Lognormal Distribution.

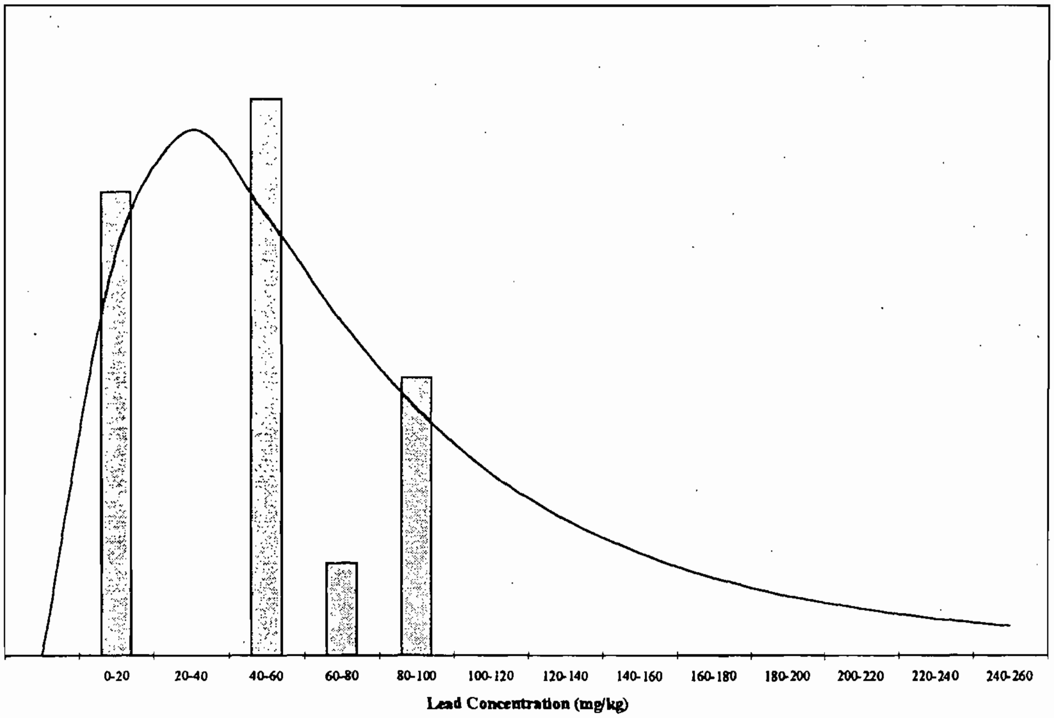

Figure 3-3. Lead Histogram and Lognormal Distribution.

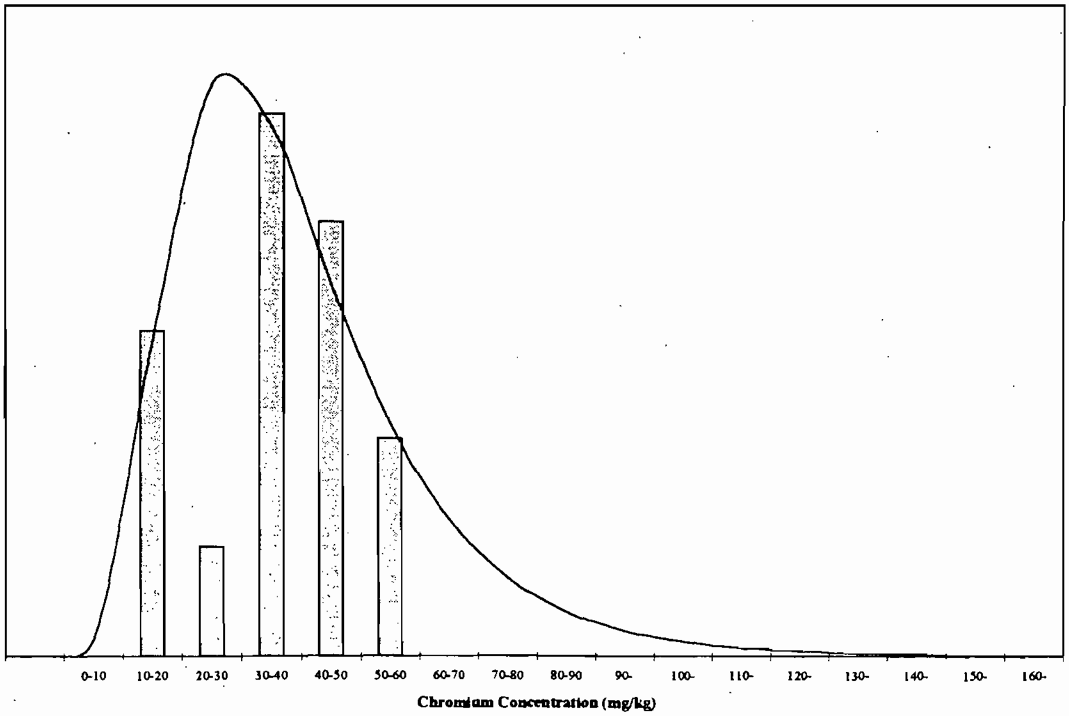

Figure 3-4. Chromium Histogram and Lognormal Distribution.

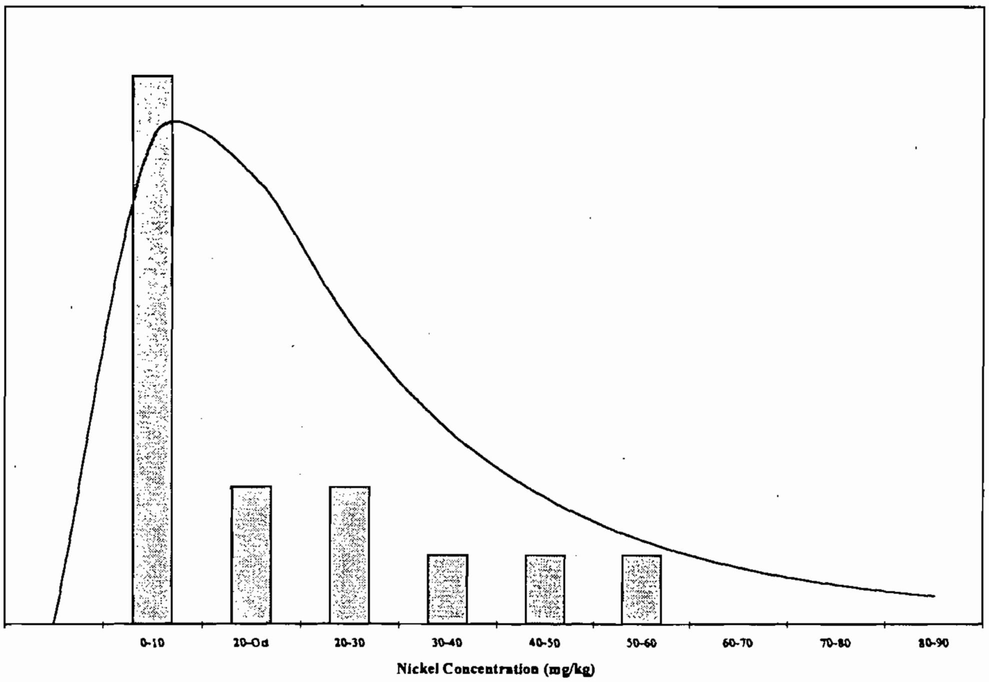

Figure 3-5. Nickel Histogram and Lognormal Distribution.

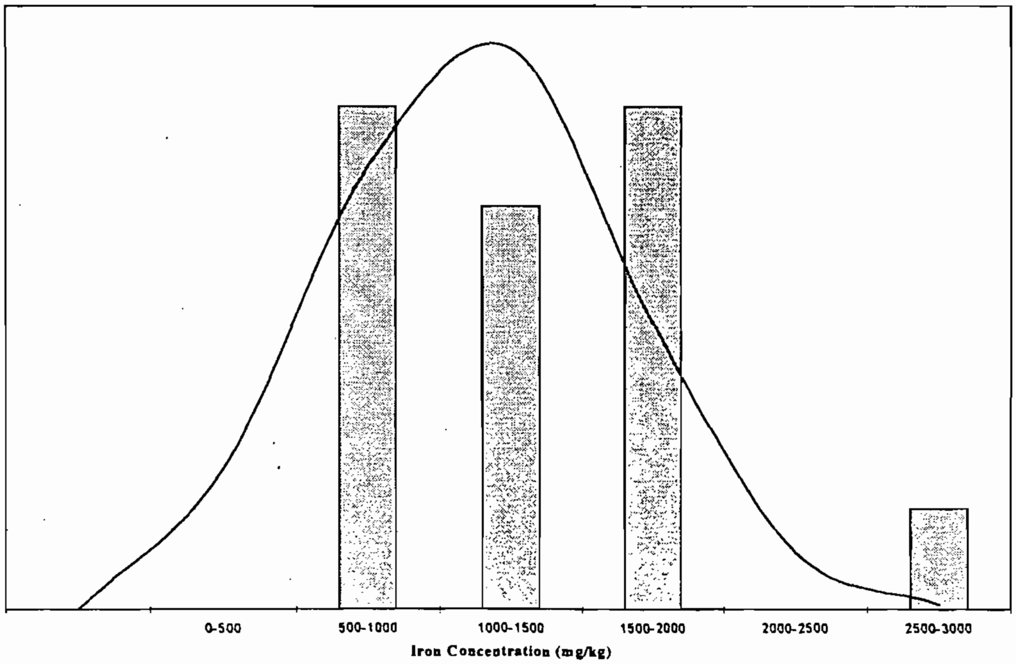

Figure 3-6. Iron Histogram and Normal Distribution. OK

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.

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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.

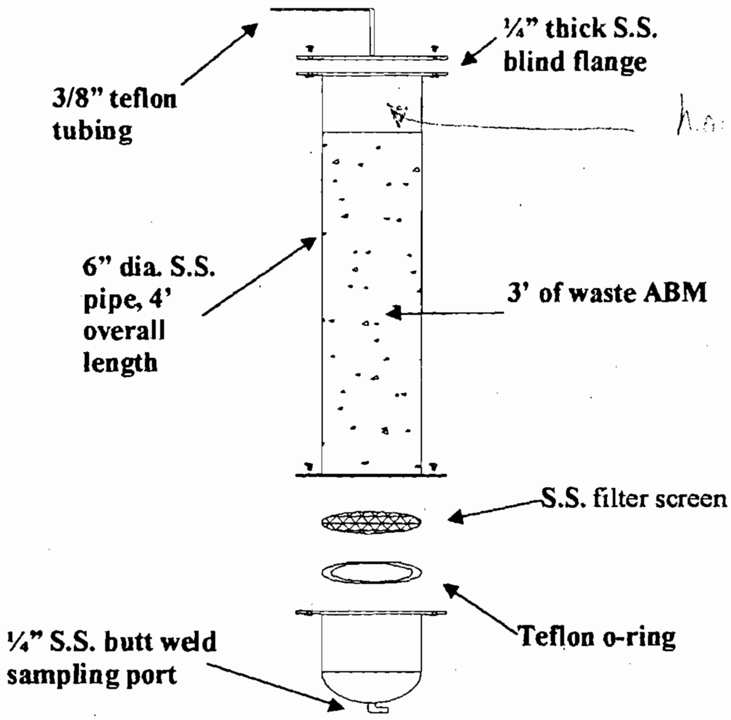

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Figure 4-1. Diagram of Lysimeter Apparatus (Brantley, 1998)

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.

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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.

SPLP SPLP SPLP

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.

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.

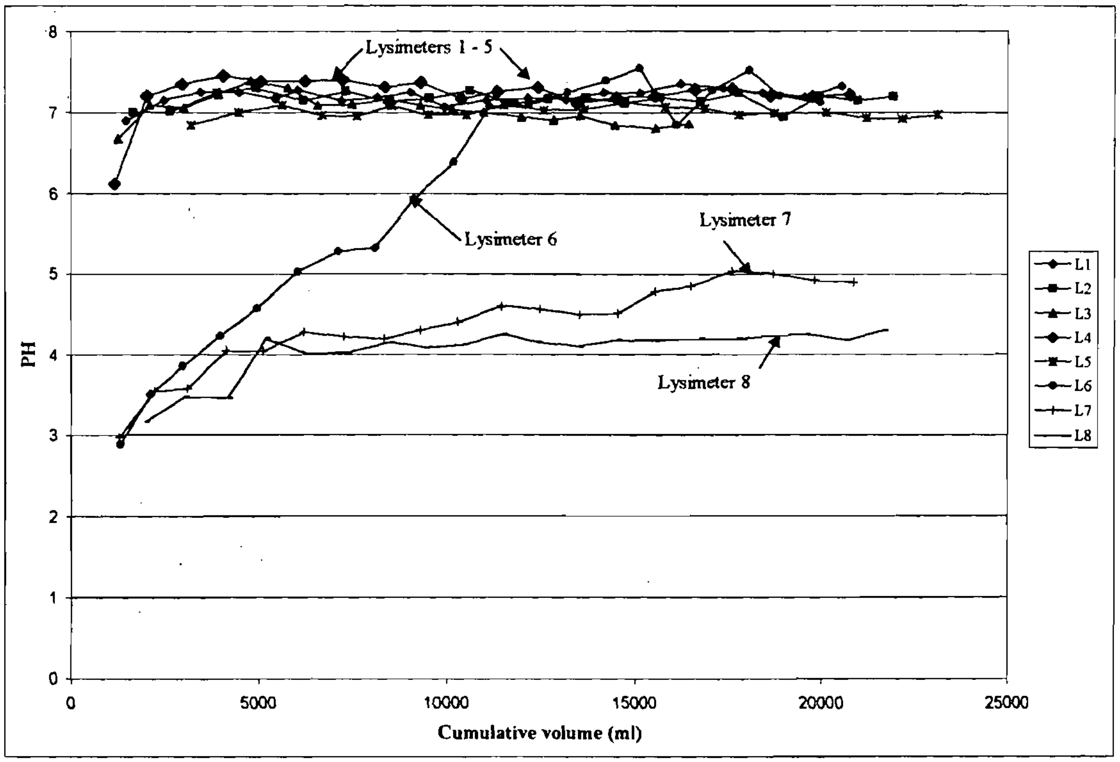

Figure 4-2. Lysimeter pH graph.

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).

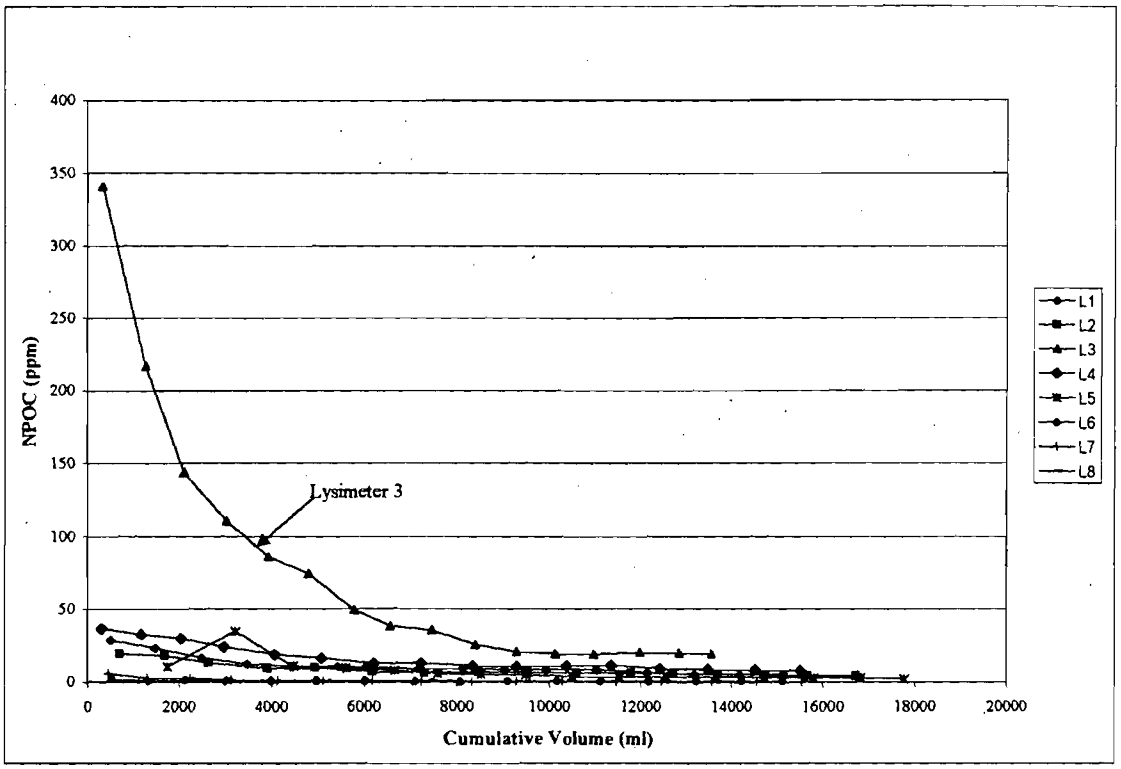

Figure 4-3. Nonpurgible Organic Carbon

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**

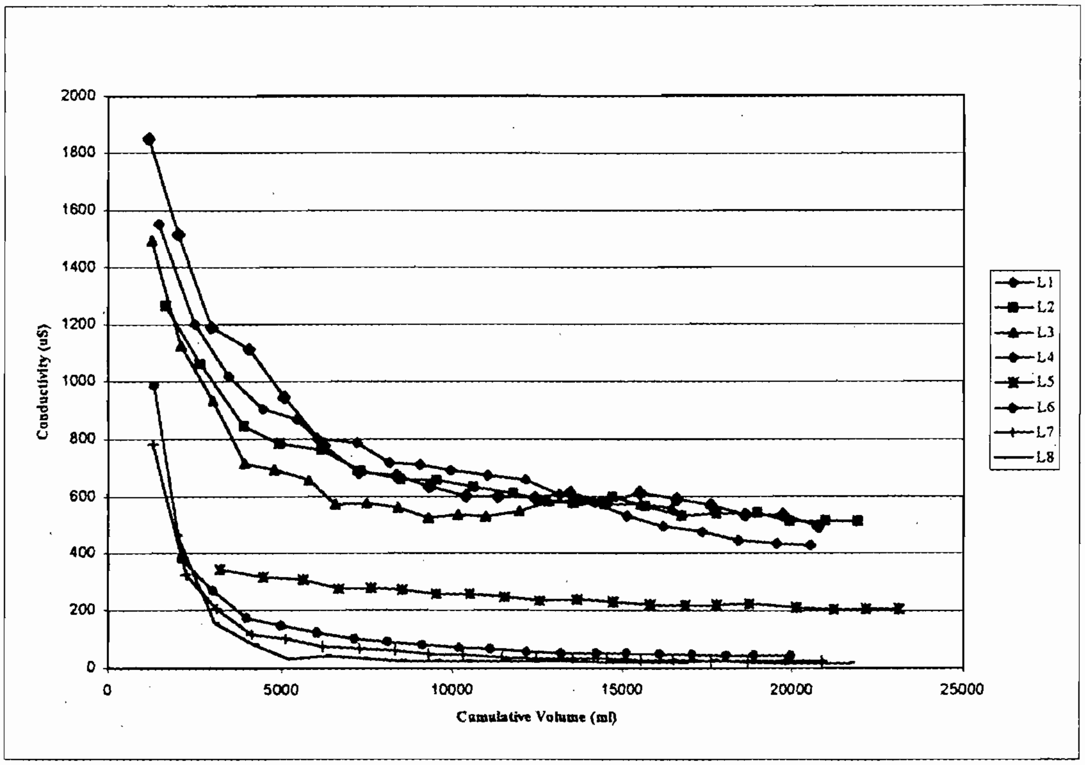

Figure 4-4. Conductivity

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.

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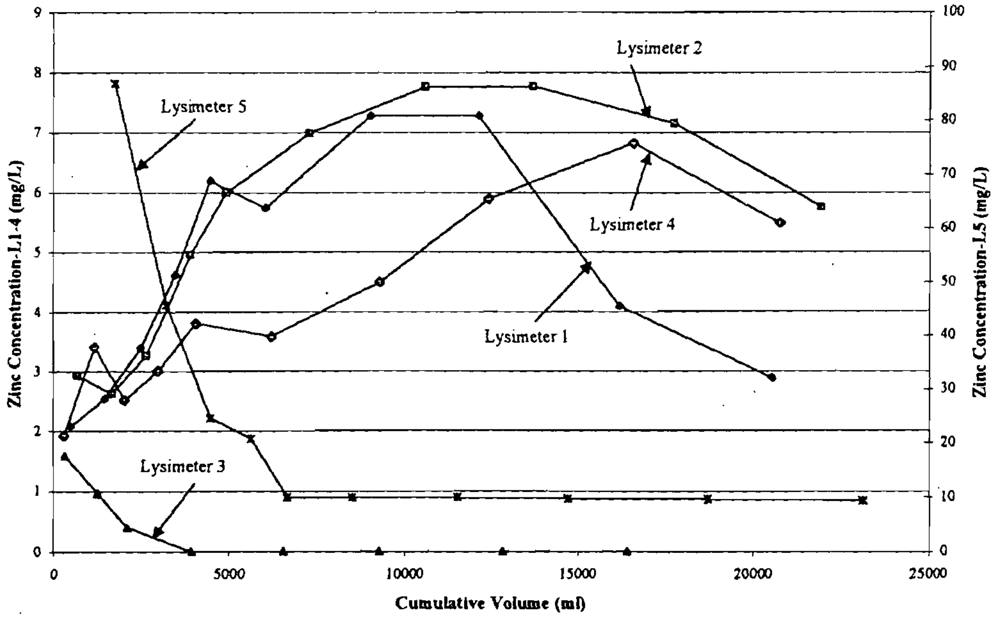

Figure 4-5. Zinc Leaching from Lysimeters.

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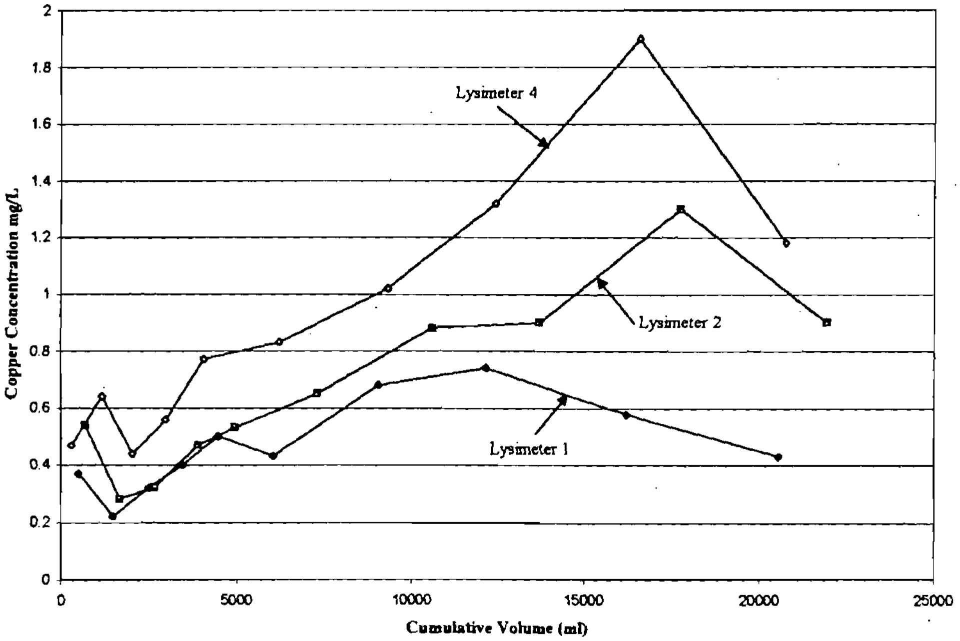


Figure 4-6. Copper Leaching from Lysimeters.

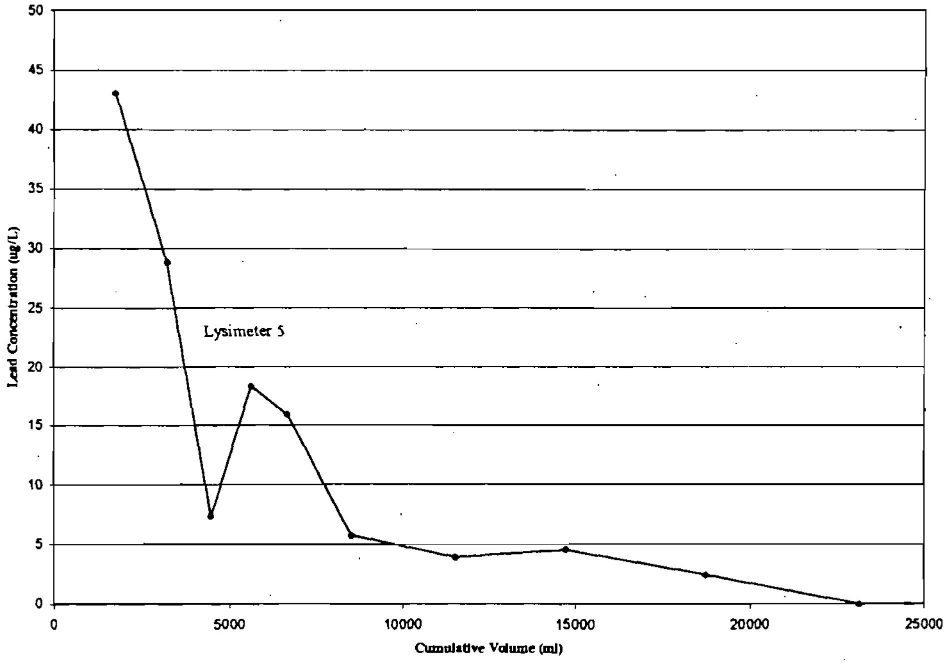


Figure 4-7. Lead Leaching from Lysimeter 5.

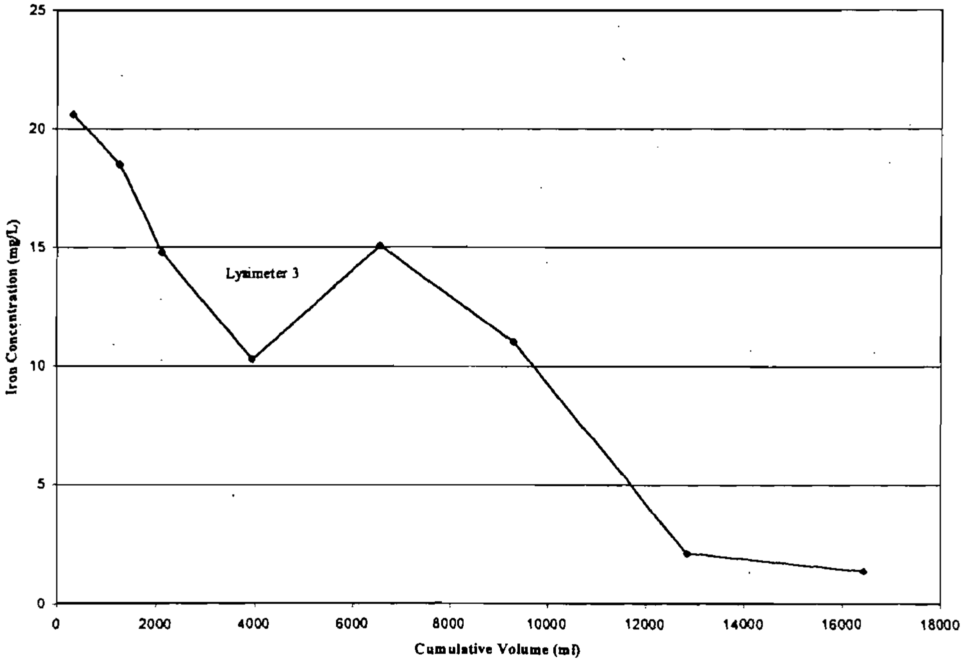


Figure 4-8. Iron Leaching from Lysimeter 3.

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 agressive?

Were the
SPLP tests
at 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.

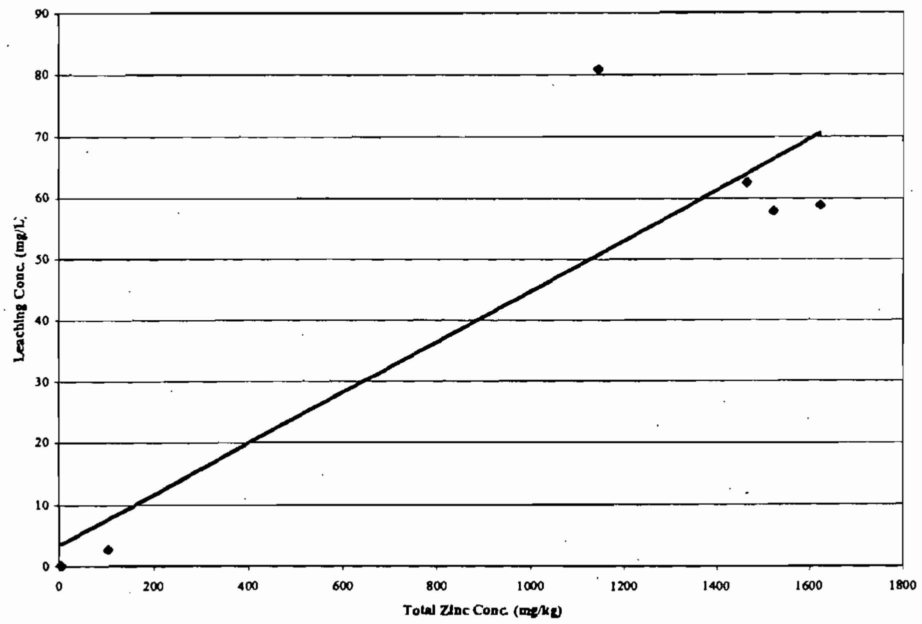


Figure 4-9. Zinc TCLP and Total Metal Correlation.

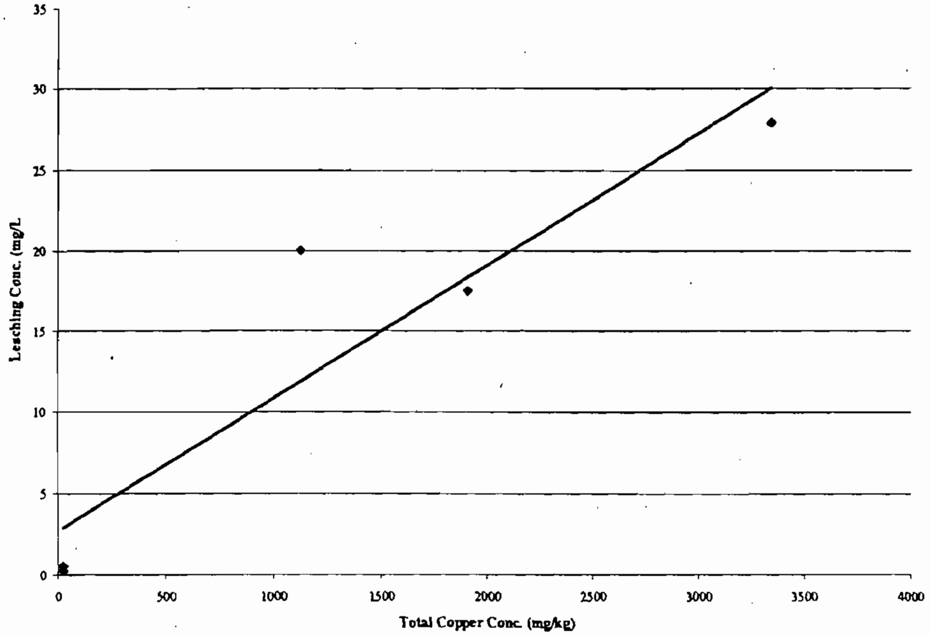


Figure 4-10. Copper TCLP and Total Metal Correlation.

not many data pts for correlation though

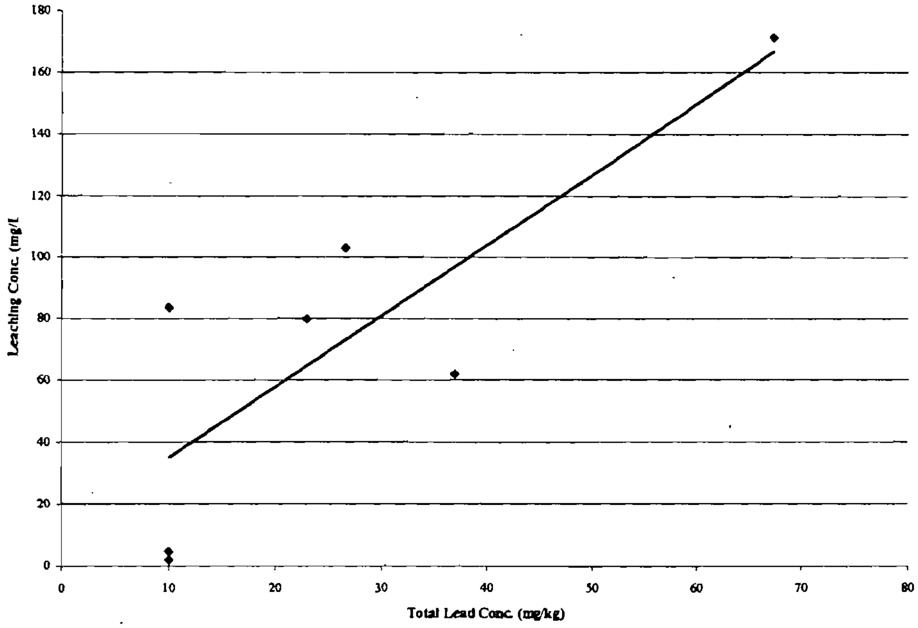
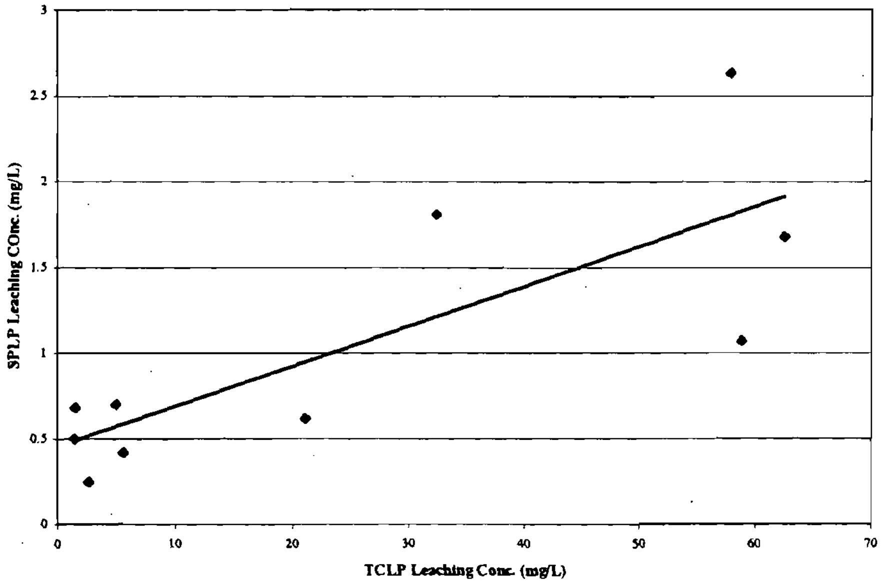


Figure 4-11. Lead TCLP and Total Metal Correlation.

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.



?

interesting

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.

?
MAX [illegible]
[illegible]
[illegible]
MAX [illegible]
SPLP [illegible]
[illegible] 2.
p. 19

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

BEST AVAILABLE COPY

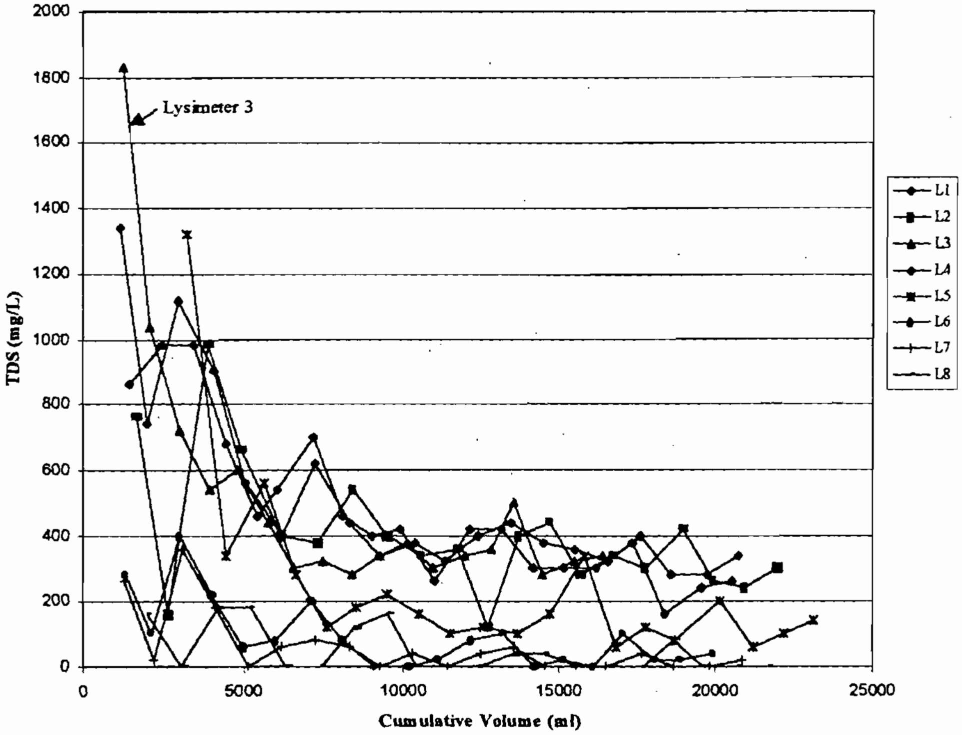


Figure B-1. TDS Leaching Curves .

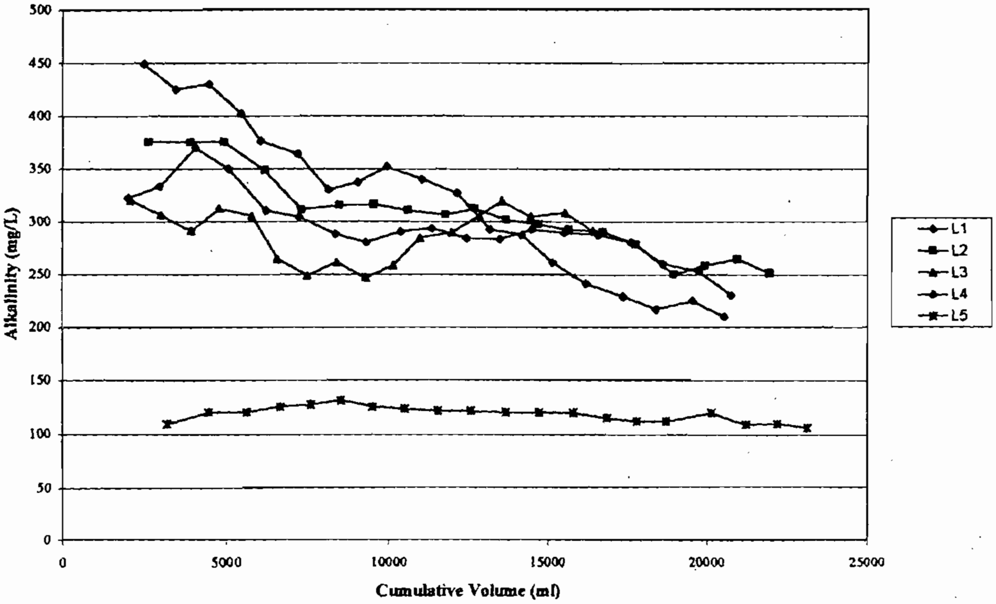


Figure B-2. Alkalinity Leaching Curves.

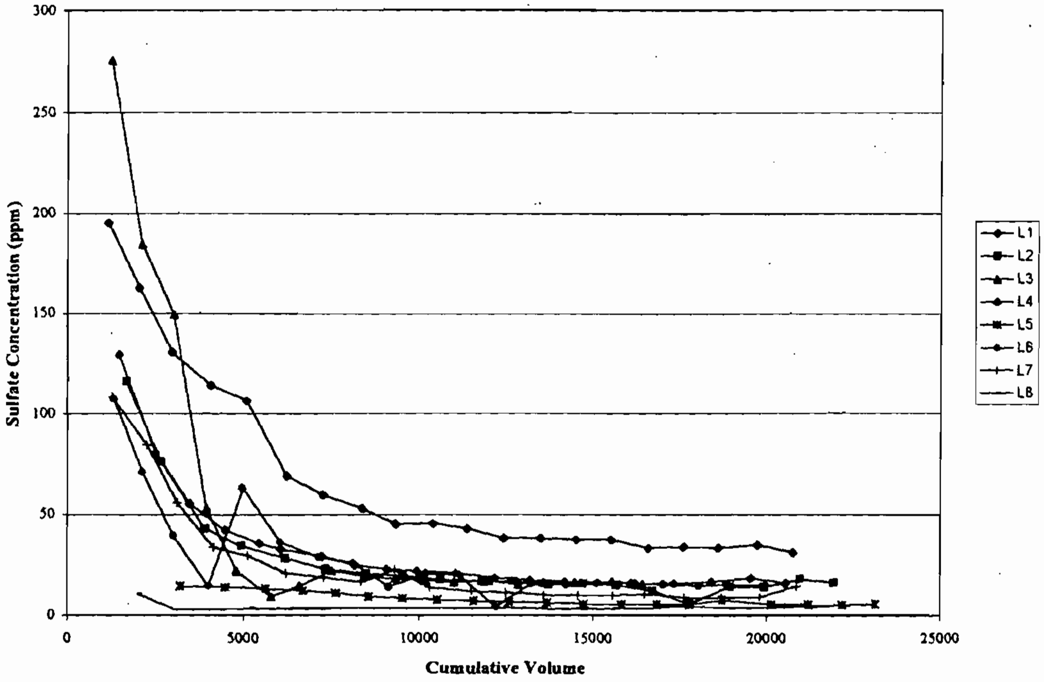


Figure B-3. Sulfate Leaching Curves

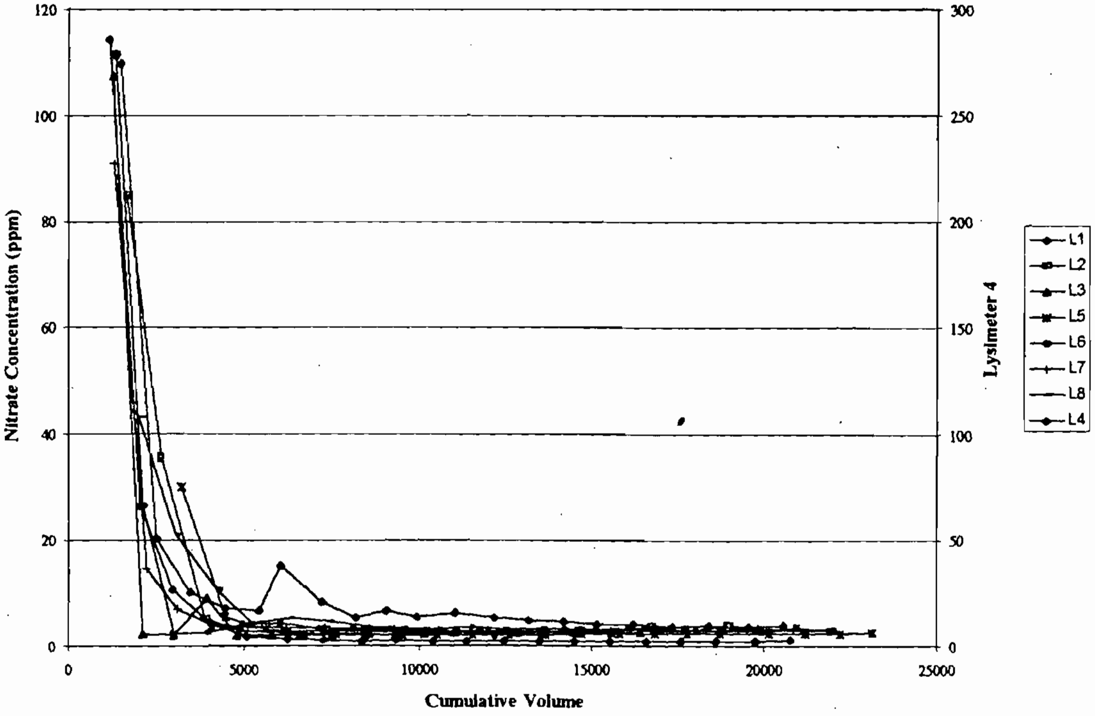


Figure B-4. Nitrate Leaching Curves

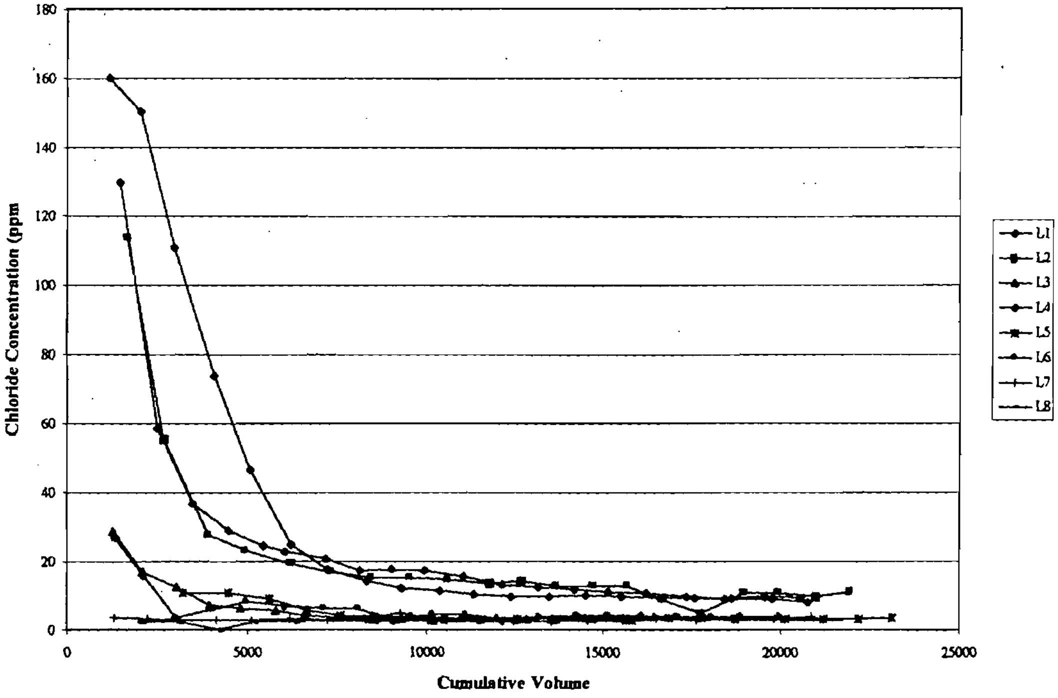


Figure B-5. Chloride Leaching Curves.

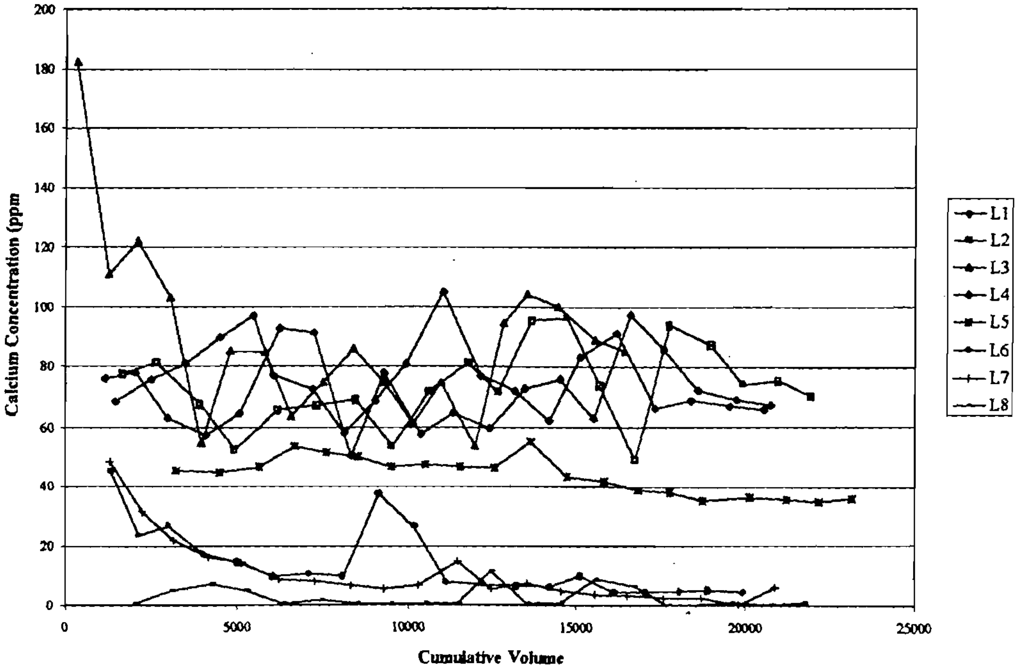


Figure B-6. Calcium Leaching Curves.

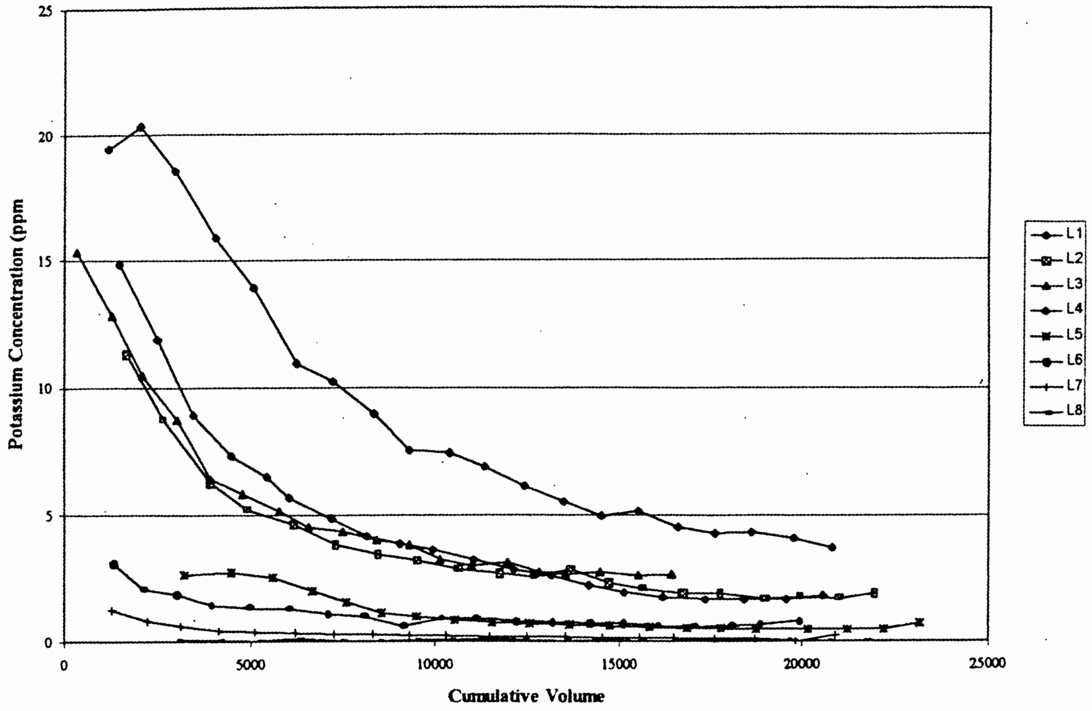


Figure B-7. Potassium Leaching Curves.

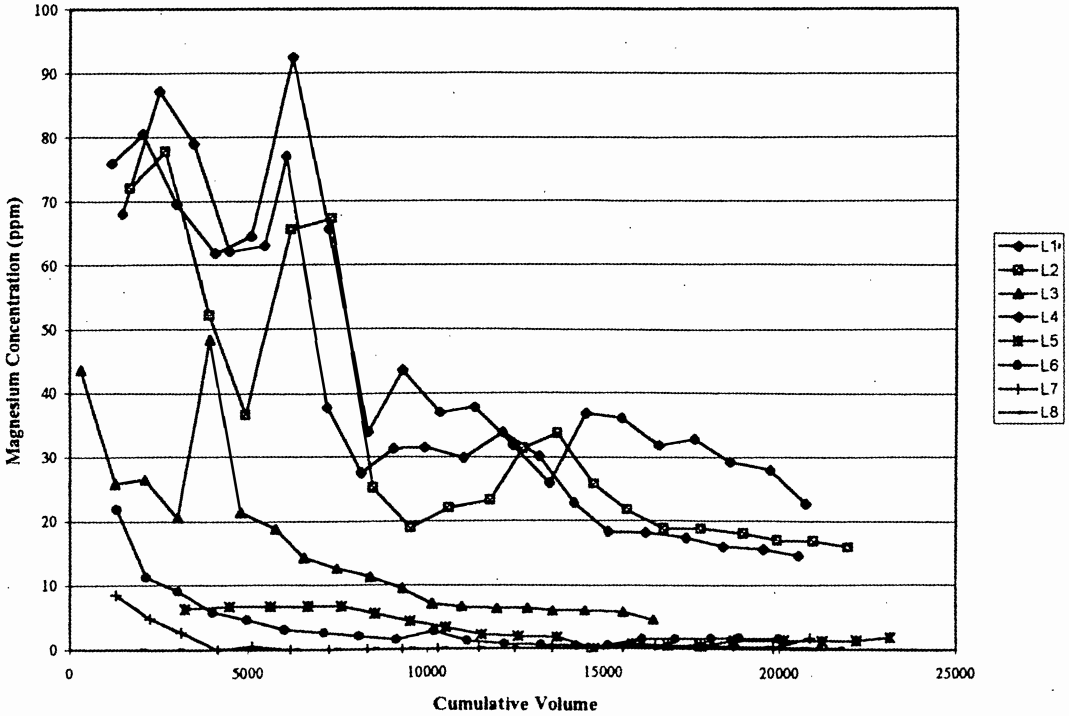


Figure B-8. Magnesium Leaching Curves.

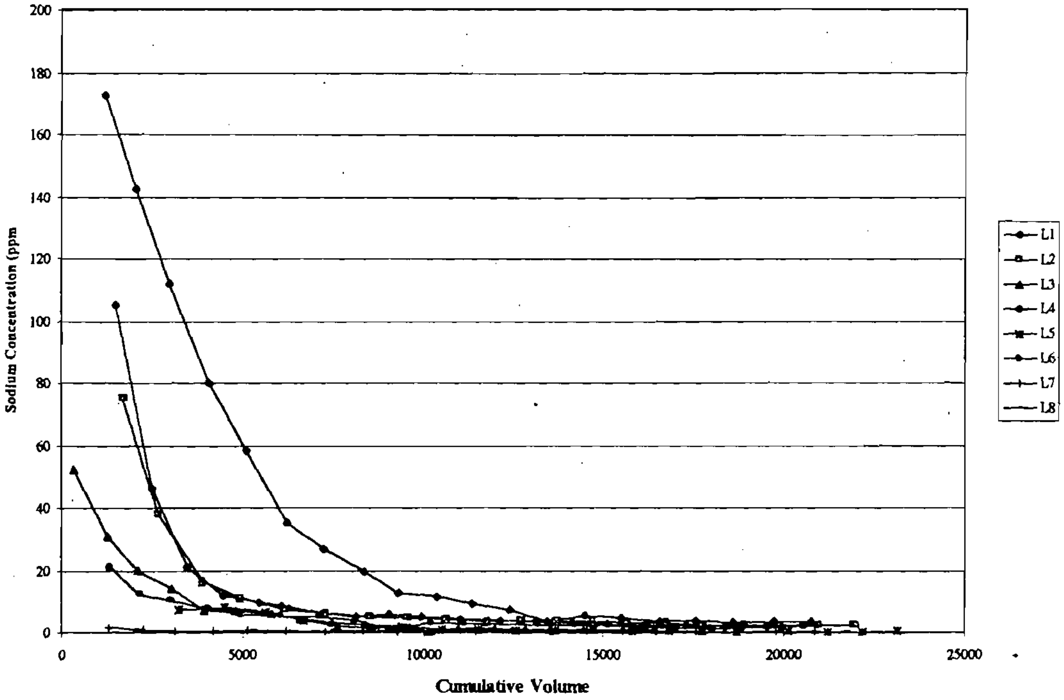


Figure B-9. Sodium Leaching Curves.

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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.