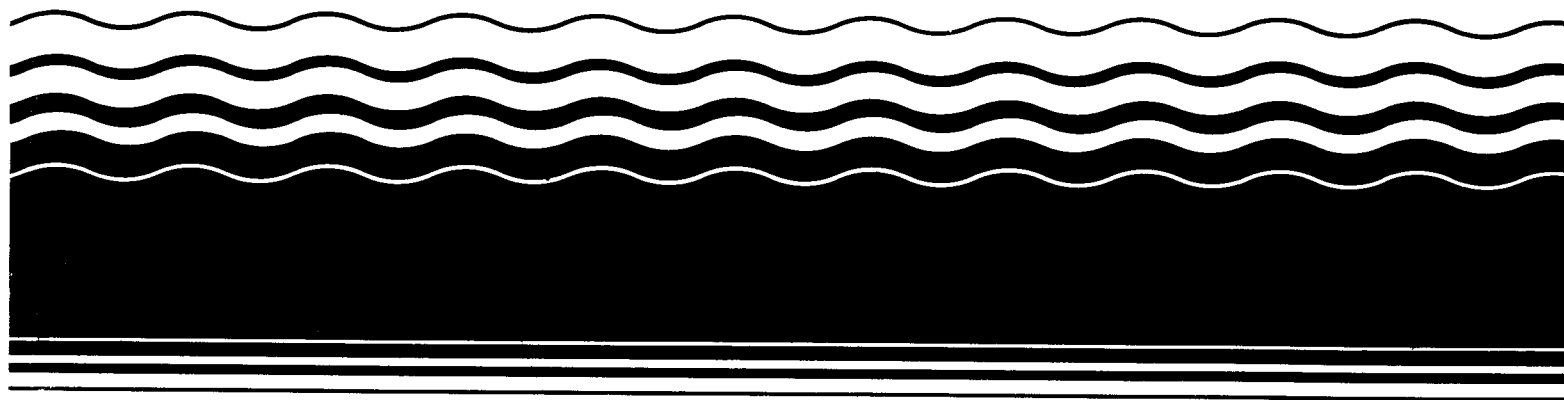

Superfund



Selection of Control Technologies for Remediation of Lead Battery Recycling Sites



EPA/540/2-91/014
July 1991

**SELECTION OF CONTROL TECHNOLOGIES
FOR
REMEDATION OF LEAD BATTERY RECYCLING SITES**

by

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FOREWORD

Today's rapidly developing and changing technologies and industrial products and practices frequently carry with them the increased generation of materials that, if improperly dealt with, can threaten both public health and the environment. The U.S. Environmental Protection Agency is charged by Congress with protecting the Nation's land, air, and water resources. Under a mandate of national environmental laws, the agency strives to formulate and implement actions leading to a compatible balance between human activities and the ability of natural resources to support and nurture life. These laws direct the EPA to perform research to define our environmental problems, measure the impacts, and search for solutions.

The Risk Reduction Engineering Laboratory is responsible for planning, implementing, and managing research, development, and demonstration programs to provide an authoritative, defensible engineering basis in support of the policies, programs, and regulations of the EPA with respect to drinking water, wastewater, pesticides, toxic substances, solid and hazardous wastes, and Superfund-related activities. This publication is one of the products of that research and provides a vital communication link between the researcher and the user community.

This report will assist federal Remedial Project Managers in planning and managing the technology selection aspects of Remedial Investigations and Feasibility Studies at sites contaminated with the by-products of lead battery recycling operations. It consolidates useful information on lead battery recycling sites, such as the following: identification and status of relevant National Priority List sites; common waste types and matrices; applicable and relevant or appropriate requirements (ARARs); clean-up target levels; key issues that affect technology selection; commonly selected treatment technologies; treatability studies; and data needs for remedial investigations. The technology assessment is done in terms of compliance with ARARs; short-term effectiveness; long-term effectiveness; reduction of toxicity, mobility, and volume; implementability; and cost.

This report supplements the more general guidance provided in *Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA, Interim Final* (USEPA, 1988c).

E. Timothy Oppelt, Director
Risk Reduction Engineering Laboratory

ABSTRACT

The objective of this report is to provide federal remedial project managers (RPMs) and their supporting contractors with information to facilitate the selection of treatment alternatives and cleanup services at lead battery recycling sites. It tailors the Remedial Investigation/Feasibility Study (RI/FS) process to lead battery recycling sites, evaluates currently used treatments, identifies remediation alternatives, and forecasts the effectiveness of treatments. Eleven RI/FSs and fifteen Record of Decision (ROD) documents for lead battery sites were the primary sources of information.

This report also addresses treatability studies at lead battery recycling sites. It presents relevant examples drawn from results of such studies. Also, it describes the technologies commonly proposed in RI/FSs and RODs. The technologies are evaluated against six of the nine EPA evaluation criteria (compliance with ARARs; long-term effectiveness and permanence; reduction of toxicity, mobility, or volume; short-term effectiveness; implementability; and cost). It compares the technologies to highlight their salient advantages and disadvantages, and to emphasize those treatments most likely to be successful in remediating lead battery recycling sites. Finally, it discusses innovative and emerging technologies, which have the potential to treat lead contaminated wastes.

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ABBREVIATIONS AND SYMBOLS

AIC	American Institute of Cancer
ANS	American Nuclear Society
ARARs	applicable or relevant and appropriate requirements
ASTM	American Society for Testing and Materials
atm	atmosphere
BDAT	Best demonstrated available technology
BOM	Bureau of Mines
CARTS	Computer-Aided Response Technologies Selector
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CERI	Center for Environmental Research Information
CLP	contract laboratory program
DLT	dynamic leach test
DQO	data quality objectives
ECAO	Environmental Criteria and Assessment Office
EDTA	ethylenediaminetetraacetic acid
EMR	electromembrane reactor
EPA	Environmental Protection Agency
EP Toxicity	extraction procedure toxicity
FWEI	Foster Wheeler Enviresponse, Inc.
GEB	Guidance and Evaluation Branch
HEAST	health effects assessment summary tables

ABBREVIATIONS AND SYMBOLS (continued)

HPDE	high density polyethylene
HSCD	Hazardous Sites Control Division
IU/BK	integrated uptake/biokinetic model
LDR	land disposal restrictions
MCL	maximum contaminant level
MEP	multiple extraction procedure
MSW	mobile soil washing
NAAQ	national ambient air quality
NCP	National Contingency Plan
NIOSH	National Institute for Occupational Safety and Health
NPDES	National Pollution Discharge Elimination System
NPL	National Priorities List
O&M	operations and maintenance
OERR	Office of Emergency and Remedial Response
ORD	Office of Research and Development
OSC	on-scene coordinator
OSHA	Occupational Safety and Health Administration
OSW	Office of Solid Waste
OSWER	Office of Solid Waste and Emergency Response
OWPE	Office of Waste Programs Enforcement
PAH	polyaromatic hydrocarbon

ABBREVIATIONS AND SYMBOLS (continued)

PCB	polychlorinated biphenyl
PCP	pentachlorophenol
POTW	publicly owned treatment works
RAGS	risk assistance guidance for Superfund
RCRA	Resource Conservation and Recovery Act
RfD	reference dose
RI/FS	remedial investigation/feasibility study
ROD	Record of Decision
RPM	remedial project manager
RREL	Risk Reduction Engineering Laboratory
SITE	Superfund Innovative Technology Evaluation (Program)
START	Superfund Technical Assistance Response Team
TAL	target analyte list
TCE	trichloroethylene
TCLP	Toxicity Characteristic Leaching Procedure
TIO	Technology Innovation Office
USACE	United States Army Corps of Engineers
USEPA	United States Environmental Protection Agency
USGS	United States Geological Survey
XRF	X-ray fluorescence

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SECTION 1

INTRODUCTION

1.1 PURPOSE

The objective of this report is to provide federal Remedial Project Managers (RPMs) and their supporting contractors with information to facilitate the selection of treatment alternatives and cleanup services at lead battery recycling sites. It tailors the Remedial Investigation/Feasibility Study (RI/FS) process to lead battery recycling sites, evaluates currently used treatments, identifies remediation alternatives, and forecasts the effectiveness of treatments.

Batteries account for more than 80% of the lead used in the United States, of which approximately 60% is reclaimed. In general, 50% of the national lead requirements are satisfied by recycled products. During the information collection activities that support this report, 29 Superfund lead battery recycling sites were identified. Twenty-two of these sites are on the National Priority List, indicating that they have been or will be the subject of RIs and FSs. In addition, 18 lead battery sites are on the RCRA Corrective Action list, with more in the process of being added. Also, as happened in the early 1980's, adverse changes in lead production costs are likely to close some operating lead recycling facilities. Some of these sites may require remediation.

This document principally assists the RPM by consolidating the following types of useful information:

- o Technologies selected via the RI/FS and removal process for other lead battery recycling sites;
- o Case studies of treatability studies on lead battery recycling site wastes;
- o Profiles of potentially applicable innovative treatment technologies;
- o Description of types of operations commonly conducted, and wastes generated at lead battery recycling sites;
- o Applicable and relevant or appropriate requirements (ARARs) identified in completed RI/FSs;
- o Key issues that commonly affect technology selection for lead battery recycling sites;
- o Recommendations regarding technology considerations at various stages of the RI/FS process;

- o A generalized assessment in terms of ARAR compliance; short-term effectiveness; long-term effectiveness; reduction of toxicity, mobility, and volume; implementability; and, costs of commonly selected technologies; and
- o Lists of pertinent references and contacts.

This report is intended to be a useful technology-oriented reference, and not a detailed instruction book on how to perform a RI/FS for a lead battery recycling site. It should be used in conjunction with the more general guidance provided in *Guidance for Conducting Remedial Investigations and Feasibility Studies under CERCLA, Interim Final* (USEPA, 1988c) and other Office of Solid Waste and Emergency Response (OSWER) guidance documents referenced at the end of this document.

By consolidating the information, data, and references of the type described above, this document assists the RPM to efficiently manage the remedy selection process in a manner that will attain the program goals, management principles, and expectations set forth in the National Contingency Plan (40CFR Sections 300.430(a)(1)(i-iii)). The ultimate goal of the remedy selection process is the selection of remedies that are protective of human health and the environment. These remedies should maintain protection over time and minimize untreated waste.

The program management principles include the following:

- o Remediation of the site by operable units when early actions are necessary or appropriate to achieve significant risk reduction quickly;
- o Operable units should be remediated in a way that is consistent with the final remedy;
- o The complexity of the site problems should be reflected in the data needs, the evaluation of alternatives, and the documentation of the selected remedy.

The program expectations for selected remedies include:

- o Treatment to address the principal threats at a site;
- o Engineering controls, such as containment, for waste that poses a relatively low long-term threat or for a situation where treatment is impractical;
- o A site-specific combination of treatment and containment to achieve protection of human health and the environment, as appropriate;
- o Institutional controls to supplement engineering controls for long-term management and to mitigate short-term impacts;
- o Use of innovative technology when such technology offers potentially comparable or superior treatment performance with fewer or lesser adverse impacts than other available approaches (or when it lowers costs for similar levels of performance than more demonstrated technologies);
- o Beneficial return of useable groundwaters wherever practicable within a reasonable time frame.

This document also fulfills Objective 37B of the Superfund Management Review Implementation Plan, which is to issue reports that identify specific technologies or combinations of technologies in order to respond to generic site classes.

1.2 SCOPE AND LIMITATIONS

This report principally addresses Superfund sites where lead-acid battery recycling operations were performed. Lead-acid battery recycling operations encompass battery breaking, component separation, lead smelting, and lead refining. These operations, which are described in more detail in subsequent sections, convert the lead in spent batteries into a marketable product. There are other Superfund sites, with battery-related contamination, where lead recycling was not the predominant operation, but these sites are not the focus of this report. Non-recycling lead battery sites, such as battery acid disposal sites, battery disposal sites (where batteries are mixed with other non-battery wastes), auto salvage operations, and battery manufacturing sites are included in the list of lead battery sites in Appendix B.

The information-gathering effort for this project focused heavily on lead battery recycling sites in the Superfund National Priority List. Project resources were insufficient to permit identification, collection, and comparison of information and data from other lead-contaminated sites (e.g., lead mining sites, ceramics manufacturing sites, or non-CERCLA lead sites) from which pertinent lessons might also have been learned.

The report focuses on: (a) control technologies that have been selected (although in many cases not yet applied) for remedial actions or removal actions at lead battery recycling sites, and (b) technologies in the EPA Office of Research and Development's Superfund Innovative Technology Evaluation (SITE) Program that are innovative and potentially applicable to heavy metals.

No attempt has been made to identify and assess the applicability of all the remediation technologies cited in Appendix D of the National Contingency Plan (40 CFR Part 300). For example, containment technologies (e.g. grouting, slurry walls, etc.) are not addressed -- except for capping, addressed only briefly -- because they were not selected for remediating the lead battery recycling sites that were identified in this project. Furthermore, the performance of containment systems for lead battery recycling sites does not differ from other applications. Sufficient knowledge of this remedy exists so that further coverage in this document was unnecessary.

This document addresses innovative treatment technologies only to a limited extent. The RPM should recognize that the applicability of existing and future novel technologies to lead battery recycling sites should be reassessed early in the RI/FS process. The SITE Program can provide the latest information on many of them.

The reader is cautioned against a premature elimination of a technology based entirely on poor performance reports in this or other documents. The reader should consider not just the technology's failure, but also the reasons that are presented for it. Only if the same failure conditions are present, in both the site scenarios and the historical information in this report, should one conclude that the technology will not work. Even then, the possibilities of pre-treatment, technology modification, or combined technologies should not be overlooked.

This document alerts the reader to regulatory and policy issues that have had or are expected to have significant effects on selection of treatment technologies. However, a comprehensive analysis of regulatory and policy issues was not within the scope of this document.

1.3 APPROACH

The basic approach of this report is to (1) identify and classify Superfund lead battery recycling sites, (2) obtain pertinent information (preferably from completed RI/FSs, and RODs), (3) review the information for useful data, facts, trends, and lessons learned, and (4) summarize pertinent information in a format that is convenient for the RPM.

This basic information collection was supplemented by the identification and limited information-gathering on approximately 20 lead battery recycling sites where removal actions were planned, in progress, or completed. It also accumulated material from discussions with RPMs; a review panel which critiqued draft versions of the document; review of pertinent regulations (e.g., RCRA land disposal restrictions), EPA guidance, research reports, and other information related to technology selection.

1.4 ORGANIZATION

This report is organized into five chapters: this introduction; three chapters that address technology considerations during the RI/FS; and a separate chapter devoted to treatability studies, which may be applicable to any stage of the RI/FS process. Appendices contain the following: a descriptive list of Superfund lead battery sites; a discussion of lead battery structure and chemical composition; the details of typical battery breaking and secondary lead smelting processes; the chemistry of lead and other heavy metals found at lead battery recycling sites; selected lead-related OSWER guidance; and a list of U.S. primary and secondary lead smelters.

SECTION 2

SCOPING THE RI/FS FOR LEAD BATTERY RECYCLING SITES

Scoping is the initial planning phase of site remediation. It is enlarged and refined as new information about the site becomes available. Scoping helps to focus activities and streamline the RI/FS, thereby preventing needless expenditures of time and money for unnecessary sampling and analyses. Scoping for a lead battery recycling site should encompass the following activities:

- o Project planning*
- o Evaluation of existing data*
- o Conducting a site visit
- o Development of a conceptual site model*
- o Identification of remedial action objectives*
- o Identification of potential remedial technologies*
- o Collecting the data necessary for potential treatability studies
- o Identification of potential applicable or relevant and appropriate requirements (ARARs)*
- o Identification of data needs*
- o Data quality objectives*
- o Preparation of project plans

This section addresses only those items marked with an asterisk (*) because they provide material supplemental to the contents of the general RI/FS guidance (USEPA, 1988c). The remaining items are adequately addressed in the scoping section of the general RI/FS guidance.

2.1 PROJECT PLANNING

There are a number of individuals and organizations with considerable experience in selection of control technologies for lead battery recycling sites. If it is necessary to augment regional experience and capabilities, the RPM can contact the organizations listed below during the scoping phase. These contacts may offer other valuable advice or support based on recent developments in their areas of expertise.

U.S. Bureau of Mines

CONTACT: Michael Magyar FTS 634-1815	Lead industry trends (mining, smelting, refining) Lead separation process development Acid-leaching treatability studies Battery case and lead-contaminated soil characterization EPA-BOM technical assistance Interagency Agreements
---	---

U.S. EPA Engineering and Treatment Technology Support Center

CONTACT: Benjamin Blaney FTS 684-7406	Superfund Technical Assistance Response Team (START) On-going, long-term, technical assistance at two lead battery recycling sites FORUM Support Lead battery recycling site treatability studies on solidification and soils washing treatments
--	---

U.S. EPA Environmental Response Team

CONTACT: George Prince FTS 340-6740	Rapid survey of lead contamination in soil via X-ray fluorescence; past experience at several lead battery recycling sites
CONTACT: Robert Cibulskis FTS 340-6746	Computer-Aided Response Technologies Selector (CARTS), now entering the prototype testing phase of development

U.S. EPA Exposure and Ecorisk Assessment Technology Support Center

CONTACT: Robert Ambrose FTS 250-3130	Metal Speciation Equilibrium Model for Surface and Groundwater (MINTEQA2 and PRODEFA2), including past experience at several lead battery recycling sites
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U.S. EPA Health Risk Technology Support Center

CONTACT: Pei-Fung Hurst FTS 684-7300	Development of Lead Biokinetic/Uptake Model
---	---

U.S. EPA Monitoring and Site Characterization Technology Support Center

CONTACTS: Kenneth W. Brown FTS 545-2270 William Engelmann FTS 545-2664	X-ray fluorescence field survey methods, including work underway to accelerate data mapping by coupling X-ray fluorescence detector to position indicating and data transmission technology.
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2.2 EVALUATION OF EXISTING DATA

A thorough search of existing data should prevent duplication of effort. The resulting remedial investigation should be more focused and, therefore, more efficient in its expenditure of time and resources.

2.2.1 Background Information on Lead-Acid Battery Construction, Chemistry, and Recycling Procedures

If information on batteries, battery breaking, lead smelting, and the chemistry of pertinent heavy metals has not been collected, the RPM should review the topics presented in Appendix A. These topics can further an understanding of the site situation, which in turn would improve preliminary judgements about the suitability of proposed treatments. In addition, the RPM must try to obtain detailed information about the operational and disposal practices at the specific site.

Exchanging information with RPMs for similar lead battery recycling sites can help to identify successful remedial approaches. A table in Appendix B describes the operations conducted at 44 CERCLA lead battery sites and their common sources of contamination.

2.2.2 Key Sources of Lead Battery Recycling Site-Related Information

In addition to the sources covered in the general RI/FS Guidance (USEPA, 1988c), there is a substantial body of useful information available to the RPM. The key to Superfund information and technical assistance sources is *Technical Support Services for Superfund Site Remediation*, 2nd Edition, EPA/ 540/8-90/011, October 1990 -- available at no cost from the Center for Environmental Research Information at FTS-684-7562. It includes descriptions of technical support sources and brokers, automated information systems, publications, and other sources of information.

If the USEPA-authored documents cited in the References and Bibliography are not already accessible, the RPM can arrange to obtain them in a short time, at no cost from either the Superfund Document Information Center at FTS-382-6940 or the Center for Environmental Research Information at FTS-6847562. The EPA regional library can also loan hard copies or microfiche files.

This project has collected a considerable number of RI/FSs for lead battery recycling sites in one location -- the USEPA Technical Assistance Section, Technical Support Branch, Risk Reduction Engineering Laboratory, Edison, NJ at (908) 321-6632. However, this file will not be updated; one must check with the RPM (listed in Appendix B) to ensure the most up-to-date records.

To enhance their understanding of site operations, and increase the options for addressing wastes at lead battery recycling sites, some RPMs have studied the lead and lead-acid battery industries. Appendices A through F provide a substantial foundation for this education process. U.S. EPA reports contain additional process and waste characterization information resulting from the study or regulation of air, water, and solid waste pollution from lead mining, primary and secondary lead smelting, battery manufacturing, and battery recycling. The best of these reports, identified during this project, are listed below.

Inspection and Operating and Maintenance Guidelines for Secondary Lead Smelter Air Pollution Control, EPA/600/2-84/026, January 1984. NTIS # PB84149368. -- This document provides (pp. 3-22) a more detailed description of secondary lead smelter processes and operations that is found in Appendix A.

Industrial Process Profiles for Environmental Use, Chapter 27, Primary Lead Industry, EPA/600/2-80/168, July 1980. -- This document contains an overview and brief descriptions of 22 unit processes in the primary lead industry (i.e., mining and subsequent processing of the lead ore).

Lead-Acid Battery Manufacture - Background Information for Proposed Standards, EPA/450/3-79/028a, November 1979. -- This document contains an overview of the lead-acid battery industry and process description information (pp. 3-1 to 3-23).

Treatment Technology Background Document, EPA/530/SW-89/048A, June 1989. NTIS # PB89-221410. -- This document describes 23 treatment technologies. It was assembled in support of the Best Demonstrated Available Technology (BDAT) selection for Third Third Wastes. Among the technologies described are chemical precipitation, high temperature metals recovery, ion exchange, stabilization, and fuel substitution.

The National Institute for Occupational Safety and Health (NIOSH) has performed numerous health hazard evaluations at lead battery facilities. These evaluations typically employ a site visit. They produce a report that provides an overview of the processes performed at the site and a summary of the health hazard evaluation. The numerous health hazard evaluation reports are listed (under Lead, by company name) in the NIOSH Publications Catalog, available in EPA libraries. NIOSH has also performed in-plant evaluations of control technologies for reducing worker exposures in the secondary lead industry. The most valuable report is:

Demonstration of Control Technology for Secondary Lead Reprocessing, 1984, Volume I, PB# 84-187-665; Volume II, PB# 84-187-673.

It describes 10 demonstrations of control technologies for reducing lead exposures in industrial lead reprocessing operations. It details the affected processes and provides an overview of the lead industry in the early 1980's. Participants included General Battery, Tonolli, East Penn, and Calwest Metals. If printed NIOSH reports are not available in a particular EPA library, they should be available on microfiche.

The U.S. Bureau of Mines is another valuable source of background information, such as the following two informative reports:

The Impact of Existing and Proposed Regulations Upon the Domestic Lead Industry, August 1988, Open File Report 55-88.

Domestic Secondary Lead Industry: Production and Regulatory Compliance Costs, 1987, Information Circular 9156.

As these titles suggest, the documents assess the economic effects of compliance on the secondary lead industry. They present process descriptions and detailed production cost estimates.

2.2.3 Key Issues to Address During Scoping

Chapter 2 of the USEPA RI/FS Guidance (1988c) addresses the topic of scoping the RI/FS. For lead battery recycling sites, additional issues should be investigated during scoping:

The Presence of Young Children or Pregnant Women on or Near the Site--

This indicates a need for prompt action, as unborn and young children are particularly susceptible to the adverse effects of lead poisoning.

Non-Process Sources of Lead--

The natural background lead in soil, leaded gasoline exhaust, spilled leaded gasoline, municipal incinerators, and plumbing systems can complicate setting cleanup levels. They can also raise problems in allocation of cleanup responsibility and costs, thus affecting selection and implementation of control technologies. Hence, such hidden sources of lead must be carefully considered when determining extent of lead contamination.

A Thorough Understanding of Site History--

Knowledge of shipping and receiving information, materials handling and storage practices, process descriptions, and waste disposal practices is critical to assessing the site contamination. It is necessary to determine whether the operation was strictly a battery breaking operation, a combination of battery breaking and other metal salvage operations, or a combined battery breaking and smelting operation.

Battery breaking operations -- Although these operations may be limited to physical breaking and separation processes, thermal processes were used in some instances to either melt the scrap lead or separate it from plastic. Reducing its volume improved handling prior to off-site shipment. Either case would require investigation of air emissions and residuals.

Salvage operations -- For other than battery breaking, the investigation must extend to other liquids and metals.

Smelting and refining sites -- Here the RPM must consider numerous additional sources and types of contamination (e.g., air emissions, smelting and refining agents, and process by-products). Table 1 summarizes the types of materials found at such sites; Table 2 summarizes alloying, smelting and refining agents.

Spent battery acid (sulfuric acid)--

Acid contamination should be thoroughly investigated for several important reasons.

- o Bulk sulfuric acid in tanks, lagoons, etc. poses a potential worker health and safety threat.
- o Sulfuric acid may promote the mobility of lead and other metals by lowering pH, thereby increasing their solubility.

TABLE 1. SUMMARY OF MATERIALS AT LEAD BATTERY RECYCLING SITES

	Battery breaking site	Integrated smelter/refiner site
1. Whole batteries	X	X
2. Polypropylene battery scrap, mixed/ unmixed/buried	X	X
3. Hard rubber battery scrap, mixed/ unmixed/buried	X	X
4. Metallic lead scrap, mixed/unmixed/ buried, powder/chips/chunks	X	X
5. Unmixed battery mud (lead sulfate and lead oxides)	X	X
6. Alloying agents *		X
7. Refining agents *		X
8. Smelting agents *		X
9. Slag/matte		X
10. Flue dust		X
11. Dross		X
12. Lead oxides		X
13. Sulfuric acid	X	X
14. Lead-contaminated soil	X	X
15. Air pollution control sludges		X
16. Water pollution control sludges	X	X
17. Wastewater	X	X
18. Debris	X	X

* See Table 2 for listing.

TABLE 2. LEAD ALLOYING, REFINING, AND SMELTING AGENTS

Alloying Agents (Watts, 1984)	Refining Agents (USBOM Circular 9156)	Smelting Agents
Antimony Arsenic Cadmium Calcium Copper Nickel Selenium Tin	Air Aluminum Ammonium Nitrate Calcium Magnesium Natural Gas Pitch Potassium Carbonate Red Lead (Pb ₃ O ₄) Sawdust Sodium Hydroxide Sodium Nitrate Steam Sulfur Zinc	Coke Limestone Scrap Iron Silica Slag

- o Sulfuric acid may decompose soil minerals, causing elevated levels of metals in surface or groundwater.
- o Soils where sulfuric acid has been dumped are likely to be high in sulfates, which may adversely affect solidification/stabilization.
- o Depressed pH caused by sulfuric acid can render surface and ground water unpotable and can adversely affect biota.

The list of likely areas for acid contamination includes the following:

- o Battery storage areas (before and after breaking), where acid could leach through soil underneath the piles
- o Soil beneath or surrounding battery breaking equipment
- o Acid collection sumps, ponds, or lagoons
- o Acid discharge areas

Although lead is generally relatively immobile in soil, the combination of enhanced solubility by sulfuric acid, porous soil, and/or geology; a high water table; and close proximity to wells or sensitive environmental areas can result in elevated mobility (and risk).

Asbestos Insulation on furnaces and other process equipment and piping--

Asbestos removal can significantly alter cleanup plans.

Physical Integrity--

Particularly with older facilities, the RPM must assess the integrity of secondary smelter structures to ensure the safety of on-site personnel.

The Volume of Material Requiring Cleanup--

This should receive careful consideration. The factors listed below have had a dramatic effect on volume at lead battery recycling sites:

Burial or incorporation of lead-contaminated wastes into various on-site structures (e.g., berms, road surfaces, etc.--a rather common practice at lead battery recycling sites)--A current survey compared to a pre-operations topographic map can provide useful clues as to where excavations may have occurred.

Off-site contamination--If not addressed early in the project, these factors can radically change the volume to be addressed by the RI/FS:

- o Contaminated waste material, sold or given away, could potentially require retrieval and cleanup.
- o Stack emissions may have extended contaminated areas off-site.
- o Wind-carried dust from on-site waste piles or other surfaces may have polluted off-site areas.
- o Nearby residences may have received elevated internal lead concentrations.
- o Runoff and flooding may have carried contamination off-site.
- o Off-site battery breaker facilities may have fed the defunct smelter. Even though operations may have ceased, these sites may be considered part of the cleanup.

Filtered or unfiltered samples--This choice may affect the amount of lead measured in ground-water.

The cleanup level selected--This choice depends upon the risk assessment approach and results. If possible, the specific approach to establishing the cleanup level should be determined early in the process. Changes in cleanup levels can radically affect the technical and economic feasibility of remedial options, and hence, the validity of the Feasibility Study.

Storage practices--Storage of raw materials and process by-products require particular attention. Unlined and/or uncovered areas are sources of contaminated runoff, leachate, and dust.

Recycling of on-site materials--Reuse of these materials may be possible. The RPM should first explore the possibility of transferring unused raw materials or materials that are commonly recycled within an operating smelter. For example, some smelters may discard slag with recoverable lead content, but the cost of off-site transportation to applicable smelters may have made recovery economically infeasible.

The RPM should arrange inspection of on-site materials by primary and secondary lead smelters and refiners, battery case manufacturers, and boilers and industrial furnace operators that burn hazardous wastes as fuel supplements. Among the two predominant types of automotive battery casings, modern polypropylene battery casings are routinely recycled. The older hard rubber cases are not recycled. However, there appears to be some potential for using hard rubber as a fuel supplement.

Solid waste products from the furnaces may be acceptable for recycling if the metal content is high enough and objectionable materials are not present, (i.e., slag for lead recovery and matte for iron recovery).

Disposal locations--Slag and other debris disposal locations may adversely affect feasibility of in situ solidification.

2.3 DEVELOPMENT OF A CONCEPTUAL SITE MODEL

Development of a conceptual site model accomplishes two goals: (1) it garners a general understanding of the site to aid in evaluating potential risks to human health and the environment, and (2) it assists in setting priorities for the activities conducted at the site.

The conceptual site model is a graphic representation of site dynamics. The site model identifies the following:

- o Potential sources of contamination (waste piles, pits, ponds, and lagoons).
- o Types of contaminants and affected media (soil, groundwater, surface water, buildings, structures, and equipment).
- o Release mechanisms and exposure pathways of potential contamination.
- o Actual and potential human and environmental receptors.

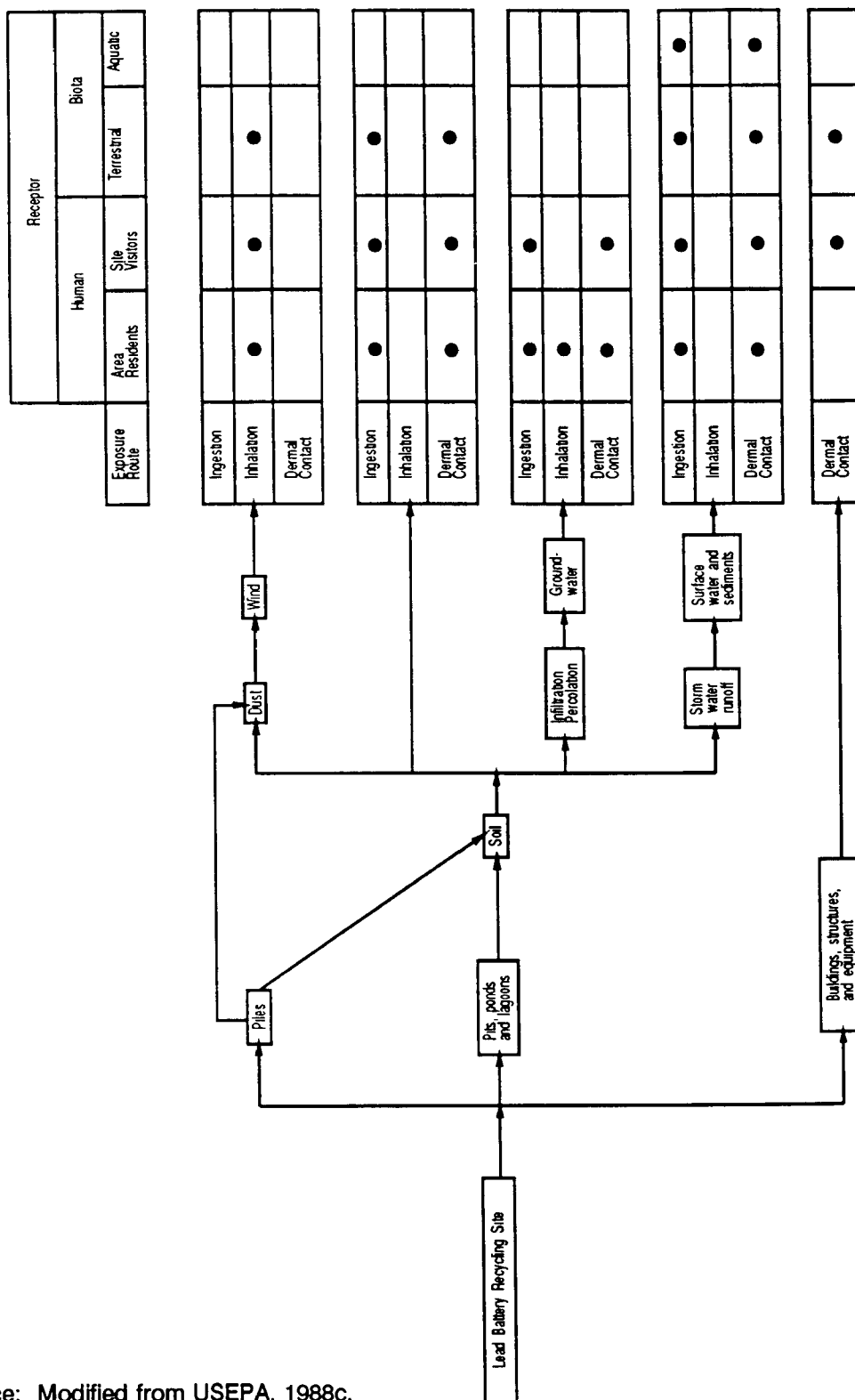
Figure 1 shows an example of a lead battery recycling site conceptual model. After evaluating the existing data and completing the site visit, the RPM should determine the contaminant release and transport mechanisms associated with his/her site.

2.4 IDENTIFICATION OF REMEDIAL ACTION OBJECTIVES

Preliminary remedial action objectives are developed during scoping to identify preliminary remedial action alternatives and RI data requirements. The objectives are based on the existing data for the site and the site conceptual model. The preliminary objectives and goals should be developed in conjunction with the preliminary ARARs and exposure assessment for the site.

Site-specific remedial action objectives for lead battery recycling sites should relate to specific sources, contaminants, exposure pathways, and receptors. The following remedial action objectives are typical of lead battery recycling sites and should be considered for the site of interest:

- o Protect human and environmental receptors against present or future, direct and dermal contact with contaminated soil or ingestion of it.
- o Minimize damage to the saturated zone and provide adequate protection of it from migrating (leaching) soil contaminants.



Source: Modified from USEPA, 1988c.

Figure 1. Example lead battery conceptual site model.

- o Protect human and environmental receptors against present or future dermal adsorption and ingestion of contaminated groundwater.
- o Protect human and environmental receptors against present or future dermal contact with contaminated structures, buildings, and equipment; also protect them from direct contact and ingestion of contaminated waste piles.
- o Protect human receptors from present or future inhalation of contaminated dust.
- o Protect human and environmental receptors against present or future, direct and dermal contact with and ingestion of contaminated sediments/sludges in pits, ponds, lagoons, and surface water.

2.5 IDENTIFICATION OF POTENTIAL REMEDIAL TECHNOLOGIES

Preliminary identification of remedial action alternatives should begin after the identification of preliminary remedial action objectives. The remedial action alternatives developed at this time will help focus the scope of the RI activities. They will delineate the degree of data collection for soils, groundwater, and other media as well as identifying the action-specific ARARs that may influence the scope of the RI. The alternatives developed at this time will be refined during the RI/FS process and may change over time as more information becomes available from the RI activities.

The remedial technologies commonly proposed in RODs for lead battery recycling sites are shown in Table 3. The RPM should investigate the application of other innovative technologies to remediation of heavy metals. For example, the Superfund Innovative Technology Evaluation (SITE) Program supports testing of innovative and emerging technologies, reports on their progress, and documents results. Some innovative technologies specific to heavy metals are discussed in Section 5: in situ solidification/stabilization, biological sorption of metals, in situ vitrification, flame reactor process, cyclone furnace, and debris washing system.

As of September 1990, 14 lead battery sites have received Records of Decision (ROD), but none have implemented treatment remedies. Four RODs have selected No Action remedies (Voortman Farm, PA; Reeser's Landfill, PA; Union Scrap Iron and Metal, MN; and NL/Taracorp/Golden Auto Parts, MN). Four other sites (Brown's Battery Breaking, PA; C&R Battery, VA; Hebelka Auto Salvage, PA; and Kas-souf-Kimerling, FL) have recently received RODs. It appears that an acid-leaching process for cleaning lead-contaminated soil and battery casings, developed by the U.S. Bureau of Mines (BOM), will be used on the pilot-scale to treat contaminated soils from the United Scrap Lead and Arcanum sites in Ohio (possibly in FY91). Other sites are moving towards implementation, after FY91, of other treatment remedies cited in RODs (e.g., solidification, battery casing washing, and off-site recycling). Also, as described in Section 4, a number of treatability studies have been conducted with varying degrees of success regarding (a) solidification/stabilization of soils, (b) washing of soils, (c) acid leaching of soils, (d) acid leaching of battery cases, (e) segregation and cleaning of battery case scrap, and (f) battery case recycling.

A number of treatment technologies have been implemented as part of removal actions by the end of 1990.

Soil--

- o Solidification of lead-contaminated soil has been completed at the Norco Battery Site, Norco, CA.

TABLE 3. REMEDIAL TECHNOLOGIES COMMONLY PROPOSED FOR LEAD BATTERY RECYCLING SITES

Contaminated medium	Technology	Description
Soil	No action	Provides a baseline against which other alternatives can be compared. Includes groundwater monitoring and land use restrictions.
	Solidification/stabilization	Mixes the waste with pozzolanic material to produce a strong, monolithic block.
	Soil washing	Uses particle size separation and an aqueous medium to extract contaminants from the soil.
	Acid leaching	Uses an acid to extract contaminants from the soil.
	Excavation and off-site disposal	Excavates and transports material for disposal in a RCRA facility.
	Capping	Installs impermeable barrier/s over the contaminated soil.
Groundwater	No action	Includes groundwater monitoring and land use restrictions.
	Precipitation/flocculation/sedimentation	Removes metals as hydroxides, carbonates, or sulfides.
	Ion exchange	Exchanges toxic ions with relatively harmless ions held by the ion exchange material.
Waste Piles	Washing	Uses a liquid medium to extract contaminants from battery casings.
	Removal and off-site disposal	Excavates and transports material for disposal in a RCRA facility.
	Separation and recycling	Separates waste piles based on differences in size, shape, and density into components of metallic lead, plastic, ebonite, and lead oxide. Recyclable materials are sold.

TABLE 3. (continued)

Contaminated medium	Technology	Description
Buildings, structures, and equipment	No action	Includes boarding-up and land use restrictions.
	Demolition	Includes complete or partial destruction of structures and disposal of debris.
	Decontamination	Washes contaminated structures/equipment with organic solvent or detergent.
Pits, ponds, lagoons, and surface water	Drainage control measures	Includes grading of the site, revegetation, and addition of storm sewers or drainage ditches.
	Pump and treat water	Same as groundwater above.
	Dredge sediments mechanically and treat together with contaminated soil	Same as soil above.

- o Solidification of lead-contaminated soil should have commenced by the end of 1990 at the Cedartown Battery Site, Cedartown, GA and at the Lee's Farm Site, Woodville, WI.
- o Liming of soil was used to elevate pH at the C&R Battery Site, Richmond, VA.
- o Liming of soil was also used to elevate pH at Murrieta School Site, Murrieta, CA. After liming, the surface was covered with a 4-inch aggregate base and a 3-inch asphalt cover.
- o Contaminated soil was stabilized with "shotcrete" at the Standard Steel & Metals Salvage Yard Site, Anchorage, AK.
- o Stabilization of contaminated soils, followed by asphalt capping, was completed in June 1988 under a consent order at the NL/Taracorp/Golden Auto Parts Site, St. Louis Park, MN.

Water--

- o Lead-contaminated surface water was treated to a discharge level of 25 ppb during removal actions at the Tonolli Site in Nesquehoning, PA. The treatment system employed several holding ponds, a rectangular clarifier, a fine particulate filtering system, two cation exchange cells, one anion exchange cell, and an activated alumina cell.

Pits, Ponds, and Lagoons--

- o Sludge in the bottom of the lagoon was removed, dewatered using a filter press, and disposed on-site at the Tonolli Site, Nesquehoning, PA.

Piles--

- o Off-site recycling of lead oxide was chosen by the owner of the Gulf Battery Exchange, Ocean Springs, MS.
- o Off-site recycling of rubber battery chips from Union Scrap Iron and Metals Site, Minneapolis, MN was accomplished by sending the material to Delatte Metals, Inc., LA.
- o Off-site recycling of batteries was part of removal actions at Standard Steel & Metals Salvage Yard, Anchorage, AK.

Buildings, Structures, and Equipment--

- o Concrete floors were scraped of soil and washed with high pressure hoses as part of removal action at United Scrap Iron & Metal, Minneapolis, MN.
- o Floors and walls were decontaminated by sweeping, vacuuming and steam cleaning at Michael Battery Company Site, Bettendorf, IA.
- o Process equipment was decontaminated/demolished under a consent decree at the NL/Taracorp/Golden Auto Parts Site, St. Louis Park, MN.

Because potential remedies are the core of the RI/FS, Section 5 evaluates them in detail. The RPM will find Section 5 valuable in planning treatability studies during the scoping phase.

2.6 IDENTIFICATION OF APPLICABLE OR RELEVANT AND APPROPRIATE REQUIREMENTS (ARARs)

Identifying ARARs assists the RPM in (1) establishing cleanup criteria for remedial alternatives; (2) planning field activities; and (3) implementing remedial action. ARARs for lead battery recycling sites have been identified by existing RI/FSs and RODs. The CERCLA Compliance with Other Laws Manual (USEPA, 1988d) will assist the RPM if it is necessary to identify other site-specific ARARs. ARARs that apply to lead-battery sites are divided into three categories:

- o Action-Specific ARARs (performance design standards, LDRs, etc.).
- o Chemical-Specific ARARs (MCLs, MCLGs, etc.).
- o Location-Specific ARARs (floodplains, wetlands, etc.).

Action-Specific ARARs

Table 4 lists potential action-specific ARARs which the RPM should consider during the remedy selection process for lead battery recycling sites. Action-specific ARARs are usually technology- or

**TABLE 4. REMEDIAL ACTIONS AT LEAD BATTERY RECYCLING SITES
AND ACTION-SPECIFIC ARAR CITATIONS**

Remedial action	Potential action-specific ARAR citation
Land disposal restrictions	40 CFR 268 Subtitle C
Placement of waste in land disposal unit	40 CFR 268 Subpart D
Slurry wall	40 CFR 268 Subpart D
Placement of liquid waste in landfill	40 CFR 264.314
Surface water control	40 CFR 264.251 40 CFR 264.273 40 CFR 264.301 40 CFR 264.221
Disposal or decontamination of equipment, structures, and soils	40 CFR 264.114
Treatment unit	40 CFR 264.190-264.192 40 CFR 254.221 40 CFR 264.251 40 CFR 264.343 40 CFR 264.601
Waste pile	40 CFR 264.251
Capping	40 CFR 264.228 40 CFR 264.310 40 CFR 264.117 40 CFR 264.258
Construction of surface impoundment	40 CFR 264.220
Closure with waste in place	40 CFR 264.228 40 CFR 264.310
Discharge of treatment system effluent	40 CFR 122.44 40 CFR 125.104 40 CFR 122.41
OSHA regulation	29 CFR Parts 1904, 1910, and 1926

Source: USEPA, 1988d.

activity-based requirements or limitations. These requirements are triggered by the selection of a particular remedial activity. Since the RPM usually considers multiple alternative actions, very different requirements can come into play. Action-specific requirements do not determine the selection of remedial alternatives; rather, they indicate how the choice must be made.

If lead-contaminated wastes (i.e., soils and fragments of battery cases) fail the Toxicity Characteristic Leaching Procedure (TCLP) test with lead levels equal to or greater than 5.0 mg/L, they are a RCRA hazardous waste (D008). Lead wastes that produce leachate levels less than 5.0 mg/L are not considered RCRA hazardous wastes (unless they are hazardous for some other reason).

RCRA hazardous wastes from pits, ponds, lagoons, groundwater, waste piles, soils, structures, or equipment must meet RCRA Subtitle C treatment, storage, and disposal requirements. RCRA Subtitle C regulations include the Land Disposal Restrictions (LDRs) in 40 CFR Part 268. The LDRs prohibit the land disposal of certain RCRA hazardous wastes unless they meet specified treatment standards. These treatment standards are based on the performance of a Best Demonstrated Available Technology (BDAT) identified for each RCRA waste code. Treatment standards may be expressed as concentrations in the TCLP extract or as total waste concentrations.

The LDR program is a "phased-in" program; each waste code has a specific effective date. The effective date for D008 characteristic lead wastes was August 8, 1990. Much of the contaminated material at lead battery recycling sites exhibits the TCLP characteristic for lead. Therefore, the LDRs are applicable to remedial actions involving placement of such hazardous wastes from lead battery recycling sites. The RPM must research the individual effective date for each Extraction Procedure Toxicity (EP Toxicity) metal identified at a site.

The treatment standard for lead wastewaters and nonwastewaters is 5.0 mg/L. Wastes treated to this level have complied with the LDR requirements. By definition, such wastes are no longer RCRA hazardous wastes. They may, therefore, be sent for disposal in a Subtitle D facility. Lead acid batteries have a separate treatment standard for thermal recovery of lead in secondary lead smelters. Therefore, LDR compliance requires that this treatment technology must be used for such wastes.

It should be noted that the storage of lead batteries with the outside shell intact is not considered land disposal because the battery shell is considered a container (See 40 CFR 264.314(d)(3)). However, battery storage is subject to the Subpart J storage standards (relating to secure storage, secondary containment in some instances, and other requirements). (See Appendix C.) Storage of other D008 lead materials prior to smelting is considered land disposal. Because large amounts of such materials remain at smelting facilities, EPA has granted a two-year national capacity variance until May 8, 1992 -- allowing such storage prior to smelting (Federal Register, June 1, 1990).

Because TCLP has replaced the EP Toxicity method, a waste may exhibit the TCLP toxicity characteristic, but not exhibit the EP Toxicity characteristic. In such a case, the waste is considered a "newly identified" characteristic waste; it is not subject to the LDRs. Therefore, if a waste exhibits the TCLP toxicity characteristic, the waste should also be analyzed using the EP toxicity method to determine whether it is subject to the LDRs. Figure 2 outlines this process in a decision tree.

It is important to note that such "newly identified" wastes, while not subject to the LDRs, are still RCRA hazardous wastes. They can only be sent for off-site disposal in an approved Subtitle C facility. If the waste is to be landfilled on-site, then the remedial alternative must meet the requirements of 40 CFR 264 regarding capping, closure, and groundwater monitoring.

On-site treatment, such as soil washing of lead-contaminated soil, produces wastewater that can generally be discharged to groundwater, nearby surface water, or a surface drainage area after treatment. These discharge methods must meet the applicable state and National Pollution Discharge Elimination System (NPDES) effluent requirements (whichever is more stringent). The wastewater treatment residues (sludges) may be hazardous and would require further treatment if they are found to be characteristic wastes, prior to disposal.

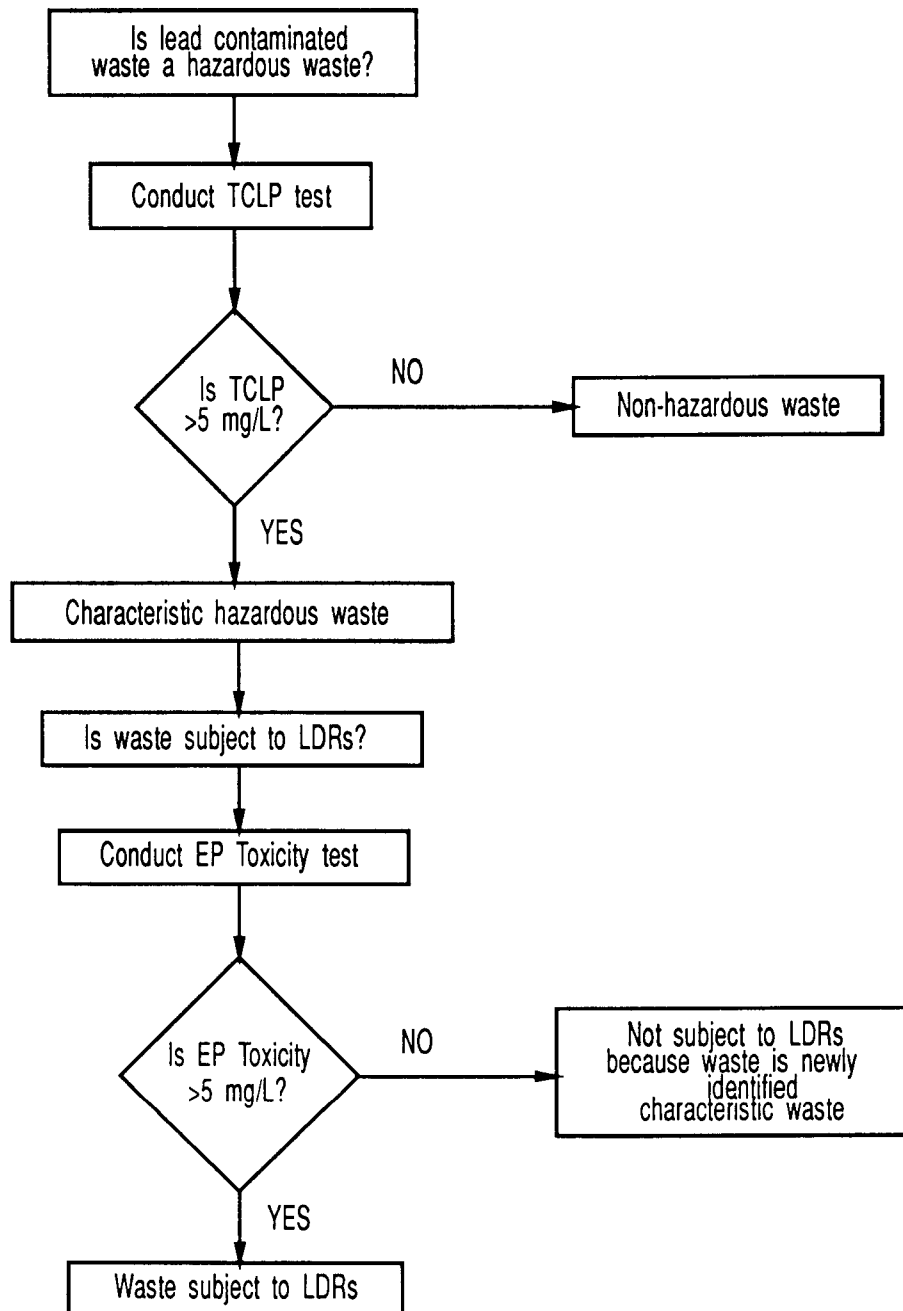


Figure 2. Decision tree showing when a waste is subject to land disposal restrictions.

Occupational Safety and Health Act (OSHA) Regulations (29 CFR Parts 1904, 1910, and 1926) apply to all work performed during implementation of a remedial action.

Chemical-Specific ARARs

Lead is the primary contaminant at lead battery recycling sites. Other metals such as antimony, arsenic, cadmium, chromium, copper, and nickel may be present in trace amounts. The RPM should be aware that these heavy metals are toxic and, therefore, their concentrations should be checked against ARARs for these metals. Table 5 lists chemical-specific ARARs for lead.

The Office of Emergency and Remedial Response (OERR) has recommended an interim cleanup level of 15 ppb for lead in potable groundwater, based on childhood health risks. The EPA has identified 10 $\mu\text{g}/\text{dL}$ of lead as a blood level of concern in young children. Lead levels above 10 $\mu\text{g}/\text{dL}$ are associated with increased risk of adverse effects on neurological development and diverse physiological functions. Lead levels in drinking water of 15 ppb and below should correlate with blood levels of lead below the concern level of 10 $\mu\text{g}/\text{dL}$ (USEPA, 1990b) (Appendix D).

Health-based lead cleanup goals for soil must be developed on a site-by-site basis, since specific ARARs do not exist at this time. The development of a health-based level is important in determining acceptable levels of residual contamination in soil. The Center for Disease Control (1985) has reported that concentrations of lead greater than 500 to 1,000 mg/kg in soil could lead to elevated lead levels in children who inhale or swallow contaminated dirt. This concentration range has been adopted by EPA (1989c) as the guidance level for childhood lead exposure at residential sites (Appendix E). OSWER is currently revising this guidance. The updated guidance, which is scheduled for publication within the next several months, will offer an alternate approach. It will use a biokinetic/uptake model for determining site-specific, health-based soil lead standards. Use of the model may result in cleanup levels outside the 500-1,000 ppm range. In addition, EPA has recently issued RODs for a number of lead battery site cleanups. Different lead action levels were implemented at specific sites under varying site conditions (Table 6). These lead action levels are examples of previously selected cleanup levels; they do not constitute guidance. A baseline risk assessment must be done at each site to establish cleanup goals.

Location-Specific ARARs

Location-specific ARARs are restrictions placed on the concentration of hazardous substances or on activities solely because they are done in specific locations. Typically, these locations include floodplains, wetlands, historic sites, and sensitive ecosystems or habitats.

The RPM should be aware that the local and state regulations may apply more stringent standards than those identified above. Since ARARs are subject to modification at any time, the RPM must keep abreast of regulatory changes. The RPM should also communicate with all appropriate state personnel (i.e., project managers, ARAR coordinators, and toxicologists) regarding changes in state and local ARARs.

2.7 IDENTIFICATION OF DATA NEEDS

Existing information will typically be insufficient to adequately define the site, plan for potential treatability studies, and evaluate remedial technologies. For a lead battery recycling site, specific needs for additional data should be included in the RI/FS Work Plan.

**TABLE 5. LEAD BATTERY RECYCLING SITES: CHEMICAL-SPECIFIC ARARs FOR LEAD
AND CRITERIA, ADVISORIES, AND GUIDANCE TO BE CONSIDERED**

Authority/Requirement/Citation	Contaminant	Media	Criteria ^a	Factors
Office of Emergency and Remedial Response and the Office of Waste Programs Enforcement	Lead	Soil	500-1,000 ppm in soil (under EPA consideration)	Interim guidance (Appendix E)
Resource Conservation and Recovery Act	Lead	Wastewater and non-wastewater	5.0 mg/L level	TCLP Toxicity
Office of Emergency and Remedial Response and the Office of Waste Programs Enforcement	Lead	Groundwater/drinking water	15 µg/L	Recommended by OERR (Appendix D)
Clean Water Act Federal Ambient Water Quality Criteria for Protection of Human Health	Lead	Surface water	50 µg/L in water	Water & fish ingestion
Clean Water Act Federal Ambient Water Quality Criteria for Protection of Human Health	Lead	Surface water	3.2 µg/L ^b	For freshwater
			5.6 µg/L	For marine
Clean Air Act National Ambient Air Quality Standards (NAAQS)	Lead	Air	1.5 µg/m ³ in air	

^a Criteria are subject to periodic review and modification.

^b Hardness dependent. This criterion value was calculated using a hardness value of 100 mg/L as CaCO₃.

**TABLE 6. SUMMARY OF SOIL LEAD ACTION LEVELS FOR LEAD BATTERY SITES
BASED ON RODs AND/OR FEASIBILITY STUDIES***

Source	Routes of exposure	Soil lead level for the protection of human health	Risk range**	Basis of decision
Preventing lead poisoning in young children by Centers for Disease Control, 1985	Childhood lead poisoning	500 to 1,000 mg/kg	NA	Recommended action level for residential areas.
EPA OSWER Directive #9355.4-02	Direct contact	500 to 1,000 mg/kg	NA	Recommended action level for residential areas.
EPA Region III, ROD, Brown's Battery Breaking Site, PA	Ingestion and inhalation	NA	NA	Action level for residential environment.
EPA Region III, ROD, C&R Battery Company, Inc. Site, VA	Ingestion	100 mg/kg	9×10^{-7} - 1.6×10^{-5} for arsenic	Action level for non-residential environment.
EPA Region III, ROD, Hebelka Auto Salvage Yard, PA	Ingestion	560 mg/kg	NA	Based on safe soil ingestion scenario.
EPA Region V, ROD, United Scrap Lead, OH	Ingestion	500 mg/kg	NA	Action level for residential environment.
EPA Region V, ROD, Arcanum Iron and Metal Site, OH	Direct contact	500 mg/kg	NA	Action level for residential environment.
EPA Region IV, Feasibility Study, Bypass 601 Groundwater Contamination Site, NC	Ingestion	500 mg/kg	NA	Action level for residential environment.
EPA Region IV, Feasibility Study, Sapp Battery Salvage Site, FL	Direct contact	79 mg/kg	NA	Action level for residential environment.
		1,150 mg/kg		Action level for work place use.
EPA Region X, ROD, Gould Site, OR	Ingestion	1,000 mg/kg	NA	Action level for residential environment.
EPA Region X, ROD, Western Processing, WA	Ingestion	NA	4×10^{-8} - 9×10^{-6} for PCB	Based on worker scenario.

* There are no data for any other sites.

** Carcinogenic potency factor has not been established for lead so a cancer risk calculation is impossible to perform at this time.

NA Not available.

Sampling and Toxicity Characteristic Leaching Procedure (TCLP) Testing

This test will determine whether lead-contaminated soils or sludges are RCRA hazardous wastes.

The Migration of Lead, Other Metals, and Arsenic

A number of soil and water properties affect migration. Models have been developed to assess chemical equilibrium for these complex interactions. Table 7 lists the types of input required for metals speciation models (Hill et al, 1989). Metals speciation models have been used at several lead battery recycling sites (eg., C&R Battery, VA; ILCO, AL; and Kassouf-Kimerling Battery, FL). As noted in Section 2.1, it is recommended that early coordination be arranged with the EPA Exposure and Ecorisk Assessment Technology Support Center to ensure the adequate collection of data for speciation models.

If undisturbed, lead tends to accumulate in the soil surface, usually in the top few centimeters. Concentrations decrease with depth (Adiano, 1986). Insoluble lead sulfide is typically immobile in the soil profile (Butler, 1954).

Depending on the chemical constituents in a system, pH can have an important impact on the solubility and, therefore mobility, of metal contaminants. Generally, metals solubility increases with decreasing pH; arsenic mobility increases with increasing pH. These trends depend on the nature of the anions and cations in the system, and the presence of chelating agents. Also, the stability of molecular and ionic species of lead are influenced by pH (Gambrell et al, 1980). The intensity of fixation of lead by soils is also influenced by pH (Misra and Pandley, 1976; Farrah and Pickering, 1977).

The Cation Exchange Capacity of Soils

This capacity affects the quantity of metal cations that can be tied up by a given amount of soil and the mobility of the metals. Therefore, the cation exchange capacity of the soils on-site should be measured.

The Organic Matter Content of a Soil

This content can affect metal mobility in two ways: by affecting oxidation reduction potentials, and by providing a source of chelating agents, which can increase metal mobility.

More Accurate Delineation of Contaminated Areas

The area and depth of soil and other media contaminated with lead are required to calculate the feed quantities to be processed. Table 8 lists some sampling techniques for various media, including portable X-ray fluorescence (XRF) detectors for measuring lead concentrations in soil.

Field-portable XRF units are being used to make in situ measurements of contaminated soil areas at lead battery recycling sites. XRF can quickly determine the presence of a target metal (Roy F. Weston, Inc., 1990). This increases the sample population and data averaging that can be used in mapping, contouring, and other interpretive methods. In situ measurements with the XRF system allow technicians to immediately locate and quantify surface lead concentrations. The instrument can also be used for collected samples from subsurface locations. The instrument detection limit for lead is 70 ppm (USEPA, 1988b). The overall advantages of XRF include 1) minimal sample preparation time, 2) rapid turnaround analysis time, 3) multi-element analytical capacity, and 4) non-destructive analysis. Its only disadvantage is the requirement for validation of the method and its applicability must be validated at each site.

TABLE 7. INPUT PARAMETERS NEEDED FOR MINTEQA2 METAL SPECIATION MODEL

Conductivity	Chloride	Potassium
pH	Bromide	Calcium
Temperature	Nitrate	Magnesium
Total dissolved solids	Nitrite	Aluminum
Hardness	Ammonia	Bicarbonate
Density	Ortho phosphate	Carbonate
Dissolved oxygen (DO)	Heavy metals	Silica
Alkalinity	Iron	Dissolved organic carbon**
Sulfate	Manganese	
Sulfides [and hydrogen sulfide or methane]*	Sodium	

The following additional redox species, where the measurement for the total shows the metal to be present:

Fe^{+2}
 Mn^{+2}
 Cr^{+6}
 Cr^{+3}

* Only to be analyzed for samples with zero DO and an H_2S odor; however, the sample collector in the field should make a note about the presence or absence of a sulfide odor.

** Perhaps dissolved concentrations of specific organic complexes if important for a specific metal.

Source: Hill et al, 1989.

In situ XRF analysis was used exclusively at Brown's battery breaking site during the Phase II activities (Roy F. Weston, 1990). A portable XRF system was used at the C&R Battery site to screen the surface soil, subsurface soil, and sediment samples collected during the field investigation. This minimized the number of samples sent to the Contract Laboratory Program (CLP) laboratories for analysis. XRF was also used to measure lead concentrations in soil and sediment. The data correlated closely with the CLP results (NUS, 1990).

Data Sufficient for a Preliminary Assessment

The data must support a preliminary assessment of the suitability of potential remedial alternatives. Table 9 lists typical data required to evaluate each type of treatment. Section 5 presents a further discussion of remedial technologies.

2.8 DATA QUALITY OBJECTIVES

Data quality objectives (DQOs) for lead battery recycling sites are formulated to ensure that data of appropriate quality and correct quantity are obtained during remedial response activities. To confirm that the data are adequate, a clear understanding of the objectives and the decision-making method must be achieved early in the project planning process. This is accomplished by the development of DQOs.

TABLE 8. TYPICAL SAMPLING PROCEDURES AT LEAD BATTERY RECYCLING SITES

Media	Sampling technique	Remarks
Soils	Grain sampler (thief)	Particularly applicable for sampling powdered or granular lead wastes such as PbO-containing soils. For surface soils only.
	Sampling trier	Primarily for core sampling near surface. Not recommended for granular materials.
	Trowel (scoop)	Generally applicable for soil samples less than 3 inches in depth.
	Veihmeyer sampler	Recommended for sampling at depths 10-15 feet. Difficult to use on stony, rocky, or very wet soil.
	X-ray fluorescence	XRF has been used successfully to detect lead in soil in concentrations as low as 70 ppm in soil. This is an in situ analysis technique. Further details can be found in Project Report EPA/600/4-87/021.
	Split spoon sampler	Mostly commonly used soil sampling device. Determines the stratification, identification, consistency, and density of the soils present at a site.
	Shelby tube sampler	Used to obtain undisturbed samples.
Waste piles	Waste pile sampler	Field-fabricated PVC pipe approximately 5 ft long and 1.25 inches in diameter, cut lengthwise, and bored into the pile by hand (basically a large sampling trier).
	Thief	Available at laboratory supply stores.
	Auger	Primarily used to sample hard or packed solid wastes or soil.
Pits, ponds, lagoons, and surface water	Coliwasa	Permits the sampling of both free-flowing liquids and slurries. Primary limitation: the sample depth cannot exceed 1.5M.
	Dipper (pond sampler)	Not available commercially, usually fabricated for particular application.
	Weighted bottle	Bottles must be fabricated in accordance with ASTM D-270 and ASTM E-300.
Groundwater	Tap	A 2-liter (minimum) sample must be collected for a minimum of 5 minutes.
	Bailer (monitoring wells)	Excellent means for collecting samples from monitoring wells. They are relatively inexpensive.
Buildings, structures, and equipment	Surface-wipe sampling	Buildings should undergo preliminary sampling for hazardous or toxic vapors and particulates.

Source: USEPA, 1984, USEPA, 1980, and USEPA, 1985a.

**TABLE 9. DATA REQUIREMENTS FOR POTENTIALLY
APPLICABLE TECHNOLOGIES**

Technology	Data requirement
<p><u>Soil</u></p> <p>Solidification/stabilization (USEPA, 1986a and Arniella et al., 1990)</p> <p>Soil washing/acid leaching (USEPA, 1989d and USEPA, 1990c)</p> <p>Capping (USEPA, 1987c)</p> <p>Off-site land disposal (USEPA, 1987e)</p>	<ul style="list-style-type: none"> o Metal concentrations o Moisture content o Bulk density o Grain-size distribution o Waste volume o Sulfate content o Organic content o Debris size and type o TCLP o Soil type and uniformity o Moisture content o Bulk density o Grain-size distribution o Clay content o Metal concentrations/species o pH o Cation exchange capacity o Organic matter content o Waste volume o Mineralogical characteristics o Debris size and type o TCLP o Extent of contamination o Depth to groundwater table o Climate o Waste volume o Soil characterization as dictated by the landfill operator and the governing regulatory agency o Waste volume o TCLP
<p><u>Groundwater</u></p> <p>Precipitation/flocculation/sedimentation (USEPA, 1989b)</p>	<ul style="list-style-type: none"> o Total suspended solids o pH o Metal concentrations o Oil and grease o Specific gravity of suspended solids

TABLE 9. (continued)

Technology	Data requirement
Ion exchange (USEPA, 1989b)	<ul style="list-style-type: none"> o Total suspended solids o Total dissolved solids o Inorganic cations and anions o Oil and grease o pH
Pumping via wells	<ul style="list-style-type: none"> o Depth to water table o Groundwater gradients o Hydraulic conductivity o Specific yield estimate o Porosity o Thickness of aquifers o Storativity
<u>Waste Piles</u>	
Off-site landfill (USEPA, 1987e)	<ul style="list-style-type: none"> o Waste pile characterization as dictated by land disposal restrictions o Waste volume o TCLP
Washing of battery casings	<ul style="list-style-type: none"> o Casing type o Bulk density o Grain-size distribution o Metal concentrations o TCLP
Recycling of battery casings	<ul style="list-style-type: none"> o Composition of battery casings o Metal concentrations o Waste volume o Other information required by recipient o TCLP

For a lead battery recycling site, DQOs should focus on site media: groundwater, soil, waste piles, pits, ponds, lagoons, contaminated buildings, structures, and equipment. For more in-depth information on DQOs the reader should consult *Data Quality Objectives for Remedial Response Actions* (USEPA, 1987b), the second volume of which details the development of DQOs for a site containing, TCE, lead, chromium, and arsenic.

SECTION 3

SITE CHARACTERIZATION

Site characterization encompasses the RI efforts to define the nature and extent of contamination at a lead battery recycling site and to collect information needed to conduct the risk assessments and to select the appropriate remedial alternative for the site. Thus it facilitates the selection of remedial action alternatives. The following site characterization activities comprise a standard RI:

- o Establish the physical characteristics of the site,
- o Define the source, nature, and extent of the contamination, and
- o Prepare a baseline risk assessment.

3.1 PHYSICAL CHARACTERISTICS

Data on the physical characteristics of the site and its surrounding areas are collected 1) to identify potential exposure transport pathways and receptor populations, and 2) to provide sufficient engineering data to develop and evaluate remedial action alternatives. The following information is used to define a site's physical characteristics:

- o A summary of previous physical data accumulated about the site.
- o Site surface features (e.g., battery breakage areas, disposal areas, pits, ponds, lagoons, buildings, and structures).
- o Site geology (depth of aquifer, type of bedrock, etc.).
- o Soil and vadose zone characteristics (permeability, moisture content, cation exchange capacity, pH, etc.).
- o Site hydrogeology (depth to water table, hydraulic conductivity, porosity, groundwater flow direction, etc.).
- o Surface water hydrology (drainage patterns, flow in surface water bodies, etc.).
- o Meteorological data (precipitation, temperature, etc.).
- o Information on demographics, land use, and water use (current/future population, location of drinking water intake, recreational areas, etc.).
- o Ecological information (wetlands, floodplains, parks, etc.).

These data may be obtained from a variety of federal, state, and local sources including aerial photographs, historical photographs, topographic surveys, site operation records, sampling/monitoring results, demographics, United States Geological Survey (USGS), zoning maps, previous investigations, and interviews with present/past site owners and employees.

3.2 SOURCE, NATURE, AND EXTENT OF CONTAMINATION

Typical sources of contamination at lead battery recycling sites are heavily contaminated soils; waste piles; groundwater; pits, ponds, and lagoons; surface water; and buildings, structures, and equipment. Geophysical surveys can be used to determine the vertical and lateral variations in both subsurface stratigraphy and subsurface metal contamination. A variety of survey techniques (e.g., ground penetrating radar, electrical resistivity, electromagnetic induction, magnetometry, and seismic profiling) can effectively detect the locations and extent of buried waste deposits. Borehole geophysics can be conducted at selected well locations in order to better characterize subsurface stratigraphy. Field screening techniques such as XRF can be used to pinpoint sampling locations at areas of greatest contamination ("hot spots"). Soil and waste samples are typically analyzed in the laboratory for the USEPA Target Analyte List (TAL) metals, TCLP toxicity, total cyanide, total organic carbon, pH, acidity/alkalinity, and cation exchange capacity. Table 10 contains a complete list of TAL metals.

Monitoring wells are installed and sampled upgradient and downgradient from a lead battery recycling site. Groundwater monitoring wells are allowed to equilibrate before water level measurement or groundwater sampling. A slug or pump test can also be performed to evaluate aquifer characteristics. Samples from the wells are analyzed for TAL metals, total cyanide, total organic carbon, total suspended solids, total dissolved solids, pH, alkalinity/acidity, hardness, sulfate, chloride, specific conductance, temperature, and dissolved oxygen. Remedial actions in some geographic regions may be based on unfiltered groundwater samples, while in others filtered or both filtered and unfiltered samples are used. Filtered sample analyses are used for concentrations of dissolved and colloidal groundwater constituents. Unfiltered sample analyses are appropriate for total metals concentrations, including metals contained in suspended sediments.

Water and sediment samples are collected from pits, ponds, lagoons, and surface water; the samples are analyzed for the chemical parameters mentioned above.

Sampling methods for tests that determine the nature and extent of contamination on building, structure, and equipment surfaces have not yet been standardized. Surface-wipe sampling is generally used. In surface-wipe sampling (wet or dry), a surface is wiped with a cotton swab or filter paper. These media may or may not be wetted with solvent. When needed, small sections of contaminated structure materials (e.g., corings) can determine the depth of contaminant penetration into porous materials such as wood or concrete. More information on this subject can be obtained from *Guide for Decontaminating Buildings, Structures, and Equipment at Superfund Sites* (USEPA, 1985a).

More details on sampling and analysis can be obtained from *Data Quality Objectives for Remedial Response Actions* (USEPA, 1987b), *Compendium of Superfund Field Operations Methods* (USEPA, 1987a), and *Test Methods for Evaluating Solid Waste - Physical/Chemical Methods* (USEPA, 1980).

3.3 RISK ASSESSMENT FOR LEAD BATTERY RECYCLING SITES

Risk assessments evaluate the likelihood and potential magnitude of human or environmental exposure to hazardous substances. Risk assessments can help determine what cleanup levels and remedies are needed. Risk assessments are multidisciplinary. They may involve expertise in numerous

TABLE 10. TARGET ANALYTE LIST (TAL) METALS

Aluminum	Calcium	Magnesium	Silver
Antimony	Chromium	Manganese	Sodium
Arsenic	Cobalt	Mercury	Thallium
Barium	Copper	Nickel	Vanadium
Beryllium	Iron	Potassium	Zinc
Cadmium	Lead	Selenium	

areas, such as chemistry, toxicology, hydrogeology, soil science, environmental modeling, and statistics. Because risk assessment is an integral part of decision-making at all stages of the RI/FS process, the project team should employ risk assessors and toxicologists early in the process.

Risk assessments at lead battery recycling sites do not differ in approach from those at other types of CERCLA sites, but there are a few unique features that are helpful to consider in planning a RI/FS.

3.3.1 Risk Assessment Guidance

The Superfund Program recommends the use of five EPA publications in assessing risk at sites.

- o Risk Assessment Guidance for Superfund (RAGS) - Volume I, Human Health Evaluation Manual (USEPA, 1989e),
- o Risk Assessment Guidance for Superfund (RAGS) - Volume II, Environmental Evaluation Manual (USEPA, 1989f).
- o Role of the Baseline Risk Assessment in Superfund Remedy Selection Decisions (USEPA, 1990f).
- o Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA. Interim Final (USEPA, 1988c).
- o The Risk Assessment Guidelines of 1986 (USEPA, 1987d).

Superfund has established a technical support center at the Environmental Criteria and Assessment Office (ECAO) in Cincinnati, Ohio (FTS-684-7300). EPA publishes quarterly Health Effects Assessment Summary Tables (HEAST). A general overview of toxicity information on the three most prevalent contaminants at lead battery recycling sites -- lead, antimony, and arsenic -- is provided below.

Lead--

Acute inorganic lead intoxication in humans is characterized by brain disease, abdominal pain, destruction of red blood cells, liver damage, kidney disease, seizures, coma, and respiratory arrest.

Chronic, low levels of lead exposure can affect the hematopoietic system, the nervous system, and the cardiovascular system. Lead inhibits several key enzymes involved in heme biosynthesis. One characteristic effect of chronic lead intoxication is anemia, due to reduced hemoglobin production and shortened erythrocyte survival. In humans, lead exposure has caused nervous system injury, reducing

hand-eye coordination, reaction time, visual motor performance, and nerve conduction velocity. The developing child seems especially sensitive to lead-induced nervous system injury.

Lead can also affect the immune system and produce gingival lead lines. Epidemiological studies have indicated that chronic lead exposures may be associated with increased blood pressure. Exposure to lead has been associated with sterility, abortion, and infant mortality. Organolead compounds are neurotoxic.

EPA has classified lead as a Group B2 carcinogen based on renal tumors in experimental animals (Federal Register, August 18, 1988).

Antimony--

Antimony exposure can irritate the gastrointestinal tract. Acute toxic effects include severe vomiting and diarrhea. With occupational exposures, rhinitis and acute pulmonary edema may occur.

Inhalation of some antimony compounds can inflame the nasal lining, the throat, the trachea, and the bronchi. It can cause both chronic obstructive lung disease and emphysema. Transient spots on the skin have been reported in workers.

Arsenic--

Acute oral exposure to arsenic can cause muscle cramps, facial swelling, cardiovascular reactions, severe gastrointestinal damage, and vascular collapse leading to death. Inhalation exposures can cause severe irritation of the nasal lining, larynx, and bronchi.

Chronic oral or inhalation exposure can produce changes in skin, including hyperpigmentation and hyperkeratosis; peripheral neuropathy; liver injury; and cardiovascular disorders. Oral exposures may be associated with peripheral vascular disease.

Arsenic is a known human carcinogen. Oral exposures are associated with skin cancer; inhalation exposures can cause lung cancer.

3.3.2 Specific Risk Assessment Issues at Lead Battery Recycling Sites

3.3.2.1 Lead Issues for Lead Battery Recycling Sites--

Before collecting environmental data at the site, the RPM should consult with the Regional Toxicologist to assess the state of risk assessments for lead-contaminated sites. Currently, EPA has no established reference dose (RfD) or slope factor to estimate the numerical noncarcinogenic and carcinogenic health impacts resulting from lead exposures. Previous toxicity values for lead, most notably those published by the American Institute of Cancer (AIC) in the Superfund Public Health Evaluation Manual, have been withdrawn and their use prohibited. Risk assessments performed before 1989 may use the AIC; however, current risk assessment guidance disqualifies its use. Furthermore, development of an RfD to evaluate the quantitative, noncancer effects of lead has been prevented by a lack of hard data on the effects in infants and young children. The multiple media providing exposure to lead also makes it difficult to gather statistics for threshold. Therefore, EPA may elect to use other risk models in evaluating the potential risks associated with lead exposure.

Because health effects may be correlated with it, the level of lead in blood is a more appropriate benchmark for health effects than an estimated intake level. The Integrated Uptake/Biokinetic (IU/BK)

model, currently being developed by the EPA and New York University as a software package, may provide a means of predicting lead levels in blood -- based on total lead uptake from inhalation, and ingestion of soil, dust, paint, food, and drinking water. The current IU/BK model estimates lead uptake and blood levels in children up to 6 years old. This model is designed to accept input of site-specific variables. If these variables are not available, the model defaults to pre-programmed values. This model is still under development; in the future, it may provide a new approach to determining lead exposure. The EPA Regional Toxicologist should be consulted before employing any lead exposure model.

An OSWER directive (Appendix E) suggests soil cleanup levels between 500 and 1,000 ppm for lead-contaminated soils in residential or potential residential areas -- taking site conditions into consideration (USEPA, 1989C). However, this directive is not sensitive to the multi-media nature of lead exposure and to the variable contribution to total lead uptake of these media at varying sites. Therefore, OERR is proposing the use of the IU/BK model, which will tailor soil cleanup levels to the site, and the RPM should check the status of the modified guidance.

3.3.2.2 Exposure Pathways for Lead Battery Recycling Sites--

Exposure assessment encompasses three objectives: to identify actual or potential exposure pathways, to characterize the potentially exposed populations, and to determine the extent of the exposure. Lead contamination at battery recycling sites may occur through one or more of the following mechanisms:

- o Ingestion of contaminated media, such as groundwater and soil;
- o Inhalation of contaminated media through exposure to entrained dust, including ingestion of particulates that have been expelled from the lungs; and
- o Dermal exposure to contaminated media.

The potential risk from each of these exposure pathways must be evaluated in the context of the site. In all cases, exposure potential, based on current and future site activities, should be evaluated for both residential and occupational exposures. If site-specific intake values are not available, the EPA-published intake values for ingestion and inhalation (USEPA, 1988e and USEPA, 1988f) should be used. These default values should provide estimates of potential exposure to site contaminants.

Children are especially sensitive to low-level effects of lead contamination. Other receptors should not be excluded, but exposure of children is of paramount importance in the assessment. The risk to children is greater, not only because of lead toxicity, but also because of childhood activity patterns. They tend to play outdoors where there is increased potential for exposure to lead in soil. Soil ingestion rates are higher for children than for other groups.

Site access is often restricted; therefore on-site exposures to contaminated media may be limited. However, should someone gain access to the site, they may experience additional exposure to contaminated soils and other particulates. Ingestion exposure is intensified by hand-to-mouth activity. In addition, contaminants may be transported home, with subsequent exposure to other family members.

3.3.2.3 Risk Assessment Data Needs--

Although the data needs for risk assessment at lead battery recycling sites are generally similar to those at other sites, some unique features should be considered: the physical nature of the waste, the use of background data, and the association of lead with other metals. If the biokinetic model is to

be used, input needs should be assessed before data are collected. Since the uptake biokinetic model is under development and therefore subject to revision, it is recommended that ECAO (FTS-684-7300) be contacted to ascertain its status and required input values.

The physical characteristics of wastes at lead battery recycling sites differ from those at many other types of sites. Large pieces of metallic lead and contaminated battery casings are unique to these sites. The consideration of these physical characteristics is important in planning the RI. Because it is unlikely that these large pieces of contaminated material will follow the same migration pathways as fine-grained material, it is necessary to assess both particle size and contaminant concentrations. For example, incidental ingestion of contaminated material may be due to various hand-to-mouth activities (such as smoking and eating). However, this mechanism would apply only to the fine-grained material; large pieces of casings or slag would not be ingested. Particle size will also determine whether contaminated material can become air-entrained.

To obtain RI data for the risk assessment, likely exposure scenarios should be developed. If the exposure routes depend on particle size, it may be necessary to conduct size separation on key soil/material samples and to analyze fine and coarse fractions separately for metal concentrations.

Adequate characterization of background lead concentrations may also be necessary -- especially for sites having high natural background concentrations or sites affected by mining activities. Plans for collecting background samples should be verified statistically to ensure that the correct numbers and sample locations are targeted.

Other metals may be associated with lead battery recycling sites. Analyses should not exclude other toxic metals. The site history should be critically evaluated to determine if other activities there may have caused other types of contamination.

SECTION 4

LEAD BATTERY RECYCLING TREATABILITY STUDIES

Treatability studies are tests designed to provide critical data needed for the evaluation and, ultimate implementation of one or more treatment technologies at a specific site. They can be run in the laboratory or the field. These studies generally aid the characterization of the untreated waste and analysis of technology performance under different operating conditions. The results may be qualitative or quantitative, depending on the level of the test. Three types of factors dictate the level of test needed; phase-related (e.g., RI/FS or RD/RA), technology-specific, and site-specific factors. More information on treatability studies can be obtained from *Guide for Conducting Treatability Studies Under CERCLA* (USEPA, 1989b) and on treatability study vendors, from *Inventory of Treatability Study Vendors - Volume I* (USEPA, 1990b).

4.1 EXAMPLES OF SITE-SPECIFIC LEAD BATTERY RECYCLING TREATABILITY STUDIES

Treatability studies on the technologies listed below and described in Section 5 have been documented in RI/FS documents for lead battery recycling sites:

- o Solidification/stabilization (cement-based) -- very effective on lead-contaminated soils.
- o Soil washing -- promising in the laboratory, but unsuccessful at two sites because of material handling problems.
- o Acid-leaching (Bureau of Mines process) -- promising, but still in bench-scale development.
- o Recycling of battery casings -- (Canonie Environmental Services Corp. process) claimed to produce approximately 75 percent recyclable materials at Gould Site in Oregon.

4.1.1 Solidification/Stabilization of Soil

Norco Site--

Only one full-scale, on-site treatment has been completed to date at a Superfund lead battery recycling site (Norco Battery Site in California). The Norco Site had approximately 8,000 tons of soil contaminated with lead sulfate (levels up to 80,000 mg/kg). Raw untreated soils had an EP Toxicity value for lead exceeding 400 mg/L. Contaminated soils were screened to 1-1/2 in., pretreated with a 40% calcium hydroxide slurry, and set aside for 3 days before treatment by fixation. This soil was then mixed, in a mobile plant, with portland cement, fly ash, and water at a rate of 300 tons per day. Results achieved were as follows:

- o EP Toxicity and TCLP results for lead after 28 days: <5 mg/L;

- o American Nuclear Society (ANS) 16.1: greater than leach index of 12; and
- o Unconfined compressive strength: >500 psi (Martyn, EPA Region 10, personal communication, 1990).

C&R Battery Site--

HAZCON, Inc. conducted a bench-scale treatability study at the C&R Battery Site in Virginia to determine the solidification reagents and ratios most suitable to lead-contaminated soil. The concentration of lead in the EP Toxicity extract (untreated soil) was 119 mg/L. This treatability study evaluated the effectiveness of mixing various ratios of pozzolanic materials with soil, including Type I and Type II Portland cement, fly ash, lime, sodium silicate, and sodium phosphate. Only the cement-based (i.e., cement or cement with additives) blends exhibited increases in resistance to leaching of lead. The treatability results also indicated that the addition of lime and sodium silicate to the cement/soil mixture significantly decreased the leachability of the solidified material. (See Table 11.) The stabilization mixture with the smallest percent volume increase that met the EP Toxicity criterion consists of a 1:0.6:0.03 soil/cement/sodium silicate ratio (by weight). Unconfined compressive strength test results indicated 28-day compressive strengths greater than 1,400 psi for the solidified materials (NUS, 1990).

Gould Site--

A bench-scale study -- conducted by Weston Services, Inc. on soil and sediment from the Gould Site in Oregon -- suggested that Portland cement, cement kiln dust, and lime kiln dust, mixed with the soil and sediment at specific increments, improved the consistency, structural stability, and non-leachability of the contaminated materials. Table 12 summarizes the TCLP laboratory test data for the various admixtures (Dames and Moore, 1988).

A pilot-scale treatability test was conducted at the Gould site by Canonie Environmental to collect the information needed to select a formulation for stabilization of waste materials left on the site following remediation. The program demonstrated that a mix of approximately 14 percent Portland cement Type I-II, 25 percent cement kiln dust, and 35 percent water successfully stabilized soils and waste products crushed to 1/8-in. size. As shown in Table 13, this formulation met all the physical strength and long-term stability requirements for on-site disposal (Canonie Environmental, undated).

Sapp Battery Site--

A treatability study was conducted at the Sapp Battery Site in Florida to evaluate cementation technologies for leachate minimization potential. The chemical fixation results indicate that the cement mixture was much more effective in binding lead than the cement, fly ash, and lime mixture. The Portland cement mixture exhibited excellent binding capacity in all samples tested. The fixed sample levels were at or near the lead detection limit of 0.06 mg/L (USEPA, 1989d), far below the maximum allowable concentration of 5 mg/L (EP Toxicity).

**TABLE 11. SOLIDIFICATION/STABILIZATION TREATABILITY STUDY RESULTS
FOR CEMENT-BASED BLENDS THAT PASSED EP TOXICITY
CRITERION FOR LEAD AT THE C&R BATTERY SITE**

Soil	Type II portland cement	Lime	Sodium silicate	Sodium phosphate	Lead concentration in extract* (mg/l)
1.0	0.6	0.067	0.0	0.0	4.2
1.0	0.6	0.7	0.03	0.0	3.2
1.0	0.6	0.0	0.08	0.0	1.5
1.0	1.0	0.0	0.0	0.0	2.4
1.0	1.0	0.055	0.0	0.0	0.8
1.0	1.0	0.0	0.0	0.067	2.2

*Concentration in EP Toxicity extract.

EP Toxicity criterion for lead is 5 mg/L.

EP Toxicity value for untreated soil was 119 mg/L.

**TABLE 12. TCLP LEACH TEST RESULTS OF BENCH-SCALE STUDY
CONDUCTED ON SOIL AND SEDIMENT FROM THE GOULD SITE**

Soil matrix	Reagent description	Lead leachate level mg/L
Soil	N/A	710.0
Sediment	N/A	24.0
Soil	20% Portland cement	ND ^a
Soil	20% Cement kiln dust (CKD)	3.5
Soil	20% Fly ash	503.0
Soil	20% Lime kiln dust	1.0
Soil	20% CKD, 0.22% sodium carbonate	36.6
Sediment	50% Cement kiln dust	ND
Sediment	50% Lime kiln dust	1.0
Soil	10% CKD, 1.4% sodium carbonate	503.0
Soil	10% Cement kiln dust	336.0
Soil	30% Cement kiln dust	1.4
Soil	10% CKD, 3.7% sodium carbonate	69.4

^aND - Sample was analyzed, but not detected.

Source: Dames and Moore, 1988

TABLE 13. SUMMARY OF CANONIE TEST RESULTS ON THE RECOMMENDED BINDER FORMULATION AT GOULD SITE

Test	Criteria	Results	Pass/fail
Unconfined Compressive Strength (ASTM C39)	50 lbs/in ² gauge (psig)	255 psig to 1,432 psig	Pass
Extraction Toxicity Procedure (EPA Method 1310)	5 ppm	0.8 ppm to 1.7 ppm	Pass
Permeability (USACE EM-110-2-1906)	10 ⁻⁴ cm/sec (less than surrounding soil)	Up to 3x10 ⁻⁶ cm/sec	Pass
Long-Term Leaching (ANSI/ANS 16.1)	No specific criteria	Less than 4 ppm dissolved lead (declining concentration with time)	Pass
Wet/Dry Test (ASTM 4843)	Less than 30% wt. loss	Less than 0.06% wt. loss	Pass
Potential Reactivity of Aggregates (ASTM C289)	Classified as innocuous	Classified as innocuous	Pass

Source: Canonie Environmental, undated.

Lee's Farm--

The proprietary MAECTITE™ Process, developed by Maecorp, Inc. has been proposed as a treatment at the Lee's Farm in Wisconsin. It will stabilize contaminated waste by converting the lead into a chemical complex which is resistant to leaching. Full-scale operations are scheduled to begin in late 1990 (Maecorp, Inc., personal communication, 1990).

Cedartown Battery--

At Cedartown Battery in Georgia, a contract has been awarded for solidification of approximately 22,000 cu yd lead-contaminated soil to the following specifications (after curing 28-days): EP Toxicity \leq 50 ppb; TCLP \leq 50 ppb; MEP \leq 5 ppm; permeability \geq 1x10⁻⁶ cm/s; unconfined compressive strength \geq 50 psi; and volumetric increase \leq 50%.

Non-Lead Battery Sites--

Table 14 lists non-battery sites where stabilization/solidification has been used, is in use, or is proposed for use in remediating hazardous wastes containing lead (USEPA, 1989a). For additional information on solidification/stabilization, see Section 5.

4.1.2 Soil Washing/Acid Leaching

Soil washing is primarily a physical process whereby the contaminants which are physically and chemically adhered to the smaller soil particles (i.e., clay, silt, and humus) are separated from the larger particles. In contrast to soil washing, acid leaching dissolves contaminants by lowering the pH of the system. Soil washing and acid leaching have been tested on the laboratory- and bench-scale with promising results.

TABLE 14. NON-LEAD BATTERY SOLIDIFICATION CASE STUDIES (USEPA, 1989a)

Site/ contractor	Contaminant (concentration)	Treatment volume	Physical form	Chemical pretreatment Y/N	Binder	Percentage binder(s) added	Treatment (batch/ continuous in situ)	Disposal (on-site/ off-site)	Volume, increase %	Scale of operation
Unnamed, ENRECO	Pb/soil 2-100 ppm	7,000 yd ³	Solid/soils	N	Portland cement and proprietary	Cement (15- 20%) propri- etary additive (5%)	In situ	Landfill	Mass > 20% (volume > 30- 35%)	Full
Marathon Steel, Phoenix, AZ Silicate technology	Pb, Cd	150,000 yd ³	Dry landfill	N	Portland cement and silicates (Toxsorb TM)	Varied 7-15% (cement)	Concrete batch plant	Landfill	NA	Full
N.E. Refinery ENRECO	Oil sludges, Pb, Cr, As	100,000 yd ³	Sludges, variable	N	Kiln dust (high CaO content)	Varied, 15-30%	In situ	On-site	> Varied, ~20% average	Full
Amoco Wood River Chemfix	Oil/solids Cd, Cr, Pb	90,000,000 gal	Sludges	Y	Chemfix propri- etary	NA	Continuous flow (propri- etary process)	On-site	Average 15%	Full (site delisted in 1985)
Pepper Steel & Alloy Miami, FL VFL Technology Corporation	Oil sat. soil Pb - 1,000 ppm PCBs - 200 ppm As - 1-200 ppm	62,000 yd ³ (plus 5,000 tons of sur- face debris)	Soils	Y	Pozzolanic and proprietary	~30%	Continuous feed (mixer proprietary design)	On-site	~1%	Full
Chem Refinery, TX HAZCON	Combined metals sulfur, oil, sludges, etc.	90,000 gal (445 yd ³)	Sludges (synthetic oil sludges)	N	Portland cement and proprietary	NA	Continuous flow	On-site (secure landfill)	> Estimated 10%	Full
Chicago Waste Hauling, American Colloid	Metals: Cr, Pb, Ba, Hg, Ag	55-gal/batch (bench study)	Various		Proprietary	10-40%	Batch mix (pug mill)	NA	> Variable	Bench
John's Sludge Pit, KS/Terracon Con- sultants, Inc.	Pb, Cr, acid		Sludge		Cement kiln dust and fly ash	Varied	Batch		> Variable	Bench
Saco Tannery Waste Pits, ME, VFL Technology Corporation	Cr (> 50,000 ppm) Pb (> 1,000 ppm)	Varied	Sludge		Fly ash, quicklime	30% fly ash 10% quicklime	In situ	On-site	> 15%	Pilot
Douglasville, PA HAZCON	Zn - 30-50 ppb Pb - 24,000 ppm PCBs - 50-80 ppm Phenol - 100 µg/L Oil and grease	250,000 yd ^{3a}	Various soil/sludges	N	Portland cement and proprietary	NA	Batch	NA	NA	Pilot

TABLE 14. (continued)

Site/ contractor	Contaminant (concentration)	Treatment volume	Physical form	Chemical pretreatment Y/N	Binder	Percentage binder(s) added	Treatment (batch/ continuous in situ)	Disposal (on-site/ off-site)	Volume, increase %	Scale of operation
Portable Equip- ment, Clackamas, OR, CHEMFIX	Pb, Cu, PCBs	40 yd ³	Soil	N	Cement, silicate	NA	Batch	NA	NA	Pilot

^aTotal volume on-site.
NA - Not available.

Lee's Farm/ILCO Sites--

Two sites have unsuccessfully attempted soil washing of lead-contaminated soil. Lee's Farm in Woodville, Wisconsin attempted soil washing with EDTA after brief laboratory-and bench-scale testing. However, this attempt was discontinued when material handling problems became excessive (USEPA, 1988a). The EPA Mobile Soils Washing System (MSW) was used at the ILCO Site in Leeds, Alabama. The MSW reduced the level of lead in the ILCO soil from 47,000 to 1,300 ppm. However, severe materials handling problems -- such as fine particles clogging the filter, excessive suspended solids loading to the EDTA/lead recovery system -- prevented the MSW from cleaning up the entire site (USEPA, 1988a).

Arcanum/Lee's Farm Sites--

Researchers have investigated the process characteristics, design, and economics of a soil-washing process that employs an electromembrane reactor (EMR) to treat contaminated soils and to recover heavy metals such as lead (USEPA, 1988a). The electrowinning process uses EDTA as the chelating agent and recovers lead by electrodeposition. Treatability studies were performed on lead-contaminated soils from two Superfund sites (Arcanum near Troy, Ohio and Lee's Farm in Woodville, Wisconsin). The optimum EDTA/lead molar ratio appears to be 1.5 to 2.0 for both soils tested (USEPA, 1988a). EDTA was not effective in chelating metallic lead in the soils obtained from the Arcanum or Lee's Farm sites.

EPA Test Program--

EPA recently completed a series of laboratory tests on soil and casing samples from metal recycling sites. These tests were intended to determine, among other findings, the feasibility of using soil washing to reduce lead contamination. The soil samples from these sites were subjected to bench-scale washing cycles using water, EDTA, or a surfactant (Tide detergent), respectively. The results did not augur success for battery breaker applications. Soil washing did not remove significant amounts of lead from any of the soil fractions. The lead was not concentrated in any particular soil fraction but rather was distributed among all the fractions. A comparison of lead concentrations in the wash waters indicated that the EDTA wash performed better than the surfactant and water washes (PEI Associates, Inc., 1989). While EDTA was reasonably effective in removing lead, Bureau of Mines researchers observed that its effectiveness seemed to vary with the species of lead present (Schmidt, 1989). The Bureau also felt that there are a number of problems associated with EDTA's field application, such as the following:

- o Cost of the reagent.
- o Extreme difficulties in filtering sands and silts.
- o Complexity of recycling EDTA.
- o Variety of EDTA forms required (depending on the prevalence of various lead species).

Barth et al of EPA conducted a bench-scale study on contaminated soils from several battery cracking sites across the United States. In this study, soil washing was used as a pretreatment before solidification/stabilization (S/S). This treatment train approach is feasible because lead is more easily separated from coarse size particles. S/S is then applied to the smaller volume of fine size particles. Different washes of tap water (pH = 7), anionic surfactant (0.5%), and Na₄EDTA (3:1 molar ratio), respectively were used at a 10:1 (solution to soil) ratio for a 30-minute contact time. Results showed

that the chelating wash solution removed more lead from the raw soil than the water or surfactant washes. However, the amount removed was insignificant compared to the total lead content. The authors concluded that weathering time impacts the efficiency of separating contaminants from a soil. S/S was effective in reducing the mobility of lead from the washed fines (Barth et al, 1990).

BOM Acid Leaching--

The Bureau of Mines (BOM) conducted bench-scale studies to evaluate the performance of acid leaching solutions on lead in contaminated soil at battery recycling sites. They first subjected soil to an ammoniacal leach containing ammonium carbonate and ammonium bisulfite. This converted the lead species to lead carbonate, which would then be leached with fluosilicic acid and the lead electrowon from solution. While electrowinning the lead was feasible, its plant required a significant capital outlay.

Since the quantities of contaminated materials to be treated at a single site were relatively small, BOM decided to investigate the production of lead sulfate sludge instead of lead metal. In this case, the soil would be subjected to carbonation followed by nitric acid leaching. This would be followed in turn by the addition of sulfuric acid to precipitate the lead from the solution as lead sulfate.

Table 15 shows some representative results from the Bureau of Mines test. The results indicated that nitric acid solutions can achieve very high removal efficiencies for soil (greater than 99%) and an EP Toxicity level less than 1 mg/L (Schmidt, 1989). For additional discussion on soil washing, see Section 5.

4.1.3 Recycling of Battery Casings

There has been no actual field experience to date in the recycling of battery casings at lead battery recycling sites. BOM-conducted, bench-scale treatability studies showed good removal efficiencies (Table 16). The residual battery casing materials have an EP Toxicity lead concentration less than 5 mg/L (Schmidt, 1989).

Three battery casing separation tests were performed on Gould Site materials. One test employed equipment manufactured by MA Industries, Inc. and the other two equipment manufactured by Poly-Cycle Industries, Inc. The two companies manufactured similar equipment. However, MA Industries markets equipment for battery breaking operations, while Poly-Cycle primarily deals only with the already separated battery components. Each process is designed for spent batteries, not battery components mixed with dirt and mud. The treatability results were as follows:

- o Separated plastic components failed the TCLP lead test. Ebonite failed badly, even after washing with hydrochloric acid and deionized water.
- o A hydrochloric acid wash removed only a minor fraction of the lead contamination from the plastic.
- o A deionized water wash had little or no effect on the lead content.

These results indicate that lead is interstitial or bound into the solid plastic or ebonite matrix, rather than surficial (Dames and Moore, 1988).

A number of commercial vendors were contacted about recycling the Gould, Inc. battery casings (Tetta, 1989). Several of their facilities feed the ebonite casing component directly to a smelting furnace as a source of fuel and carbon. Most of the companies expressed reluctance because the amount of

**TABLE 15. REPRESENTATIVE RESULTS OF THE BUREAU OF MINES TREATABILITY TESTS
ON SELECTED SAMPLES OF BATTERY BREAKER SOIL WASTES**

Site/waste	Common lead species	Average^a lead total (ppm)	Leaching method	Total lead (ppm)	EP Toxicity (mg/L)
United Scrap Lead soil	Pb, PbSO ₄ , PbO _x	8,000-18,000	15% HNO ₃ , 2-hr wash and 1% HNO ₃ , 24-hr soak	200	<1.0
United Scrap Lead soil	Pb, PbSO ₄ , PbO _x	8,000-18,000	80 g/L F*, 4-hr & 20 g/L F*, 4-hr, 2-stage wash, 1% HNO ₃ , 24-hr soak	203	<1.0
Arcanum soil	Pb (6.6%), PbSO ₄	71,000	80 g/L F*, 4-hr, 50°C & 20 g/L F*, 4-hr, 50°C, 2-stage leach and 1% HNO ₃ , 24-hr wash	334	0.26
Arcanum soil	Pb (6.6%), PbSO ₄	71,000	15% HNO ₃ , 2-hr, 50°C leach and 1% HNO ₃ , 50°C, 24-hr wash	<250	<0.1
C&R Battery Soil Sample B	Pb, PbSO ₄ , PbCO ₃ , PbO ₂	71,000	15% HNO ₃ , 2-hr and 2% HNO ₃ , 24-hr wash and 1-hr water rinse	29	<0.1

^aNo initial EP Toxicity data available.

F* Fluosilicic acid

Source: Schmidt, 1989

**TABLE 16. REPRESENTATIVE RESULTS OF THE BUREAU OF MINES TREATMENT TESTS ON
SELECTED CHIP SAMPLES OF BROKEN BATTERY CASING WASTES**

Site/waste	Common lead species	Average^a lead total (ppm)	Leaching method	Total lead (ppm)	EP Toxicity (mg/L)
United Scrap lead granulated chips	PbSO ₄ , Pb	3,000	0.5% HNO ₃ , 1-hr, 20°C wash	86	<0.2
Arcanum broken chips	PbSO ₄ , Pb	3,000	1% HNO ₃ , tap water, 50°C, 24-hr, agitated	210	<3.5
C&R Battery casing chips	PbSO ₄ , Pb	175,000	1% HNO ₃ 4-hr, wash and water rinse	277	0.15
Gould buried casing chips (broken)	PbCO ₃ , PbSO ₄		Ammonium carbonate carbonation, 1% HNO ₃ , 20°C, 4-hr wash	145	0.52
Rhone-Poulenc casing chips (broken)	PbCO ₃	65,000	Calcium carbonate carbonation, 0.5% HNO ₃ , 20°C, 1-hr wash	516	3.68

^aNo initial EP Toxicity data available.

Source: Schmidt, 1989

recoverable lead in the Gould ebonite would be low and its recovery would lower their production capacity (Tetta, 1989). Several developing processes should become capable of processing waste battery piles and recovering valuable materials. The success of a particular process will depend, in part, on how strongly the lead adheres to the ebonite.

Canonie Environmental Services Corp. under contract to NL Industries, Inc. has developed a proprietary process. They claim this process is capable of recycling 75 percent of the materials at the Gould site waste.

SECTION 5

EVALUATING REMEDIAL ALTERNATIVES

5.1 REMEDIAL ACTION OBJECTIVES

At lead battery recycling sites, the general remedial action objective is to provide adequate protection for the public and the environment against ingestion, direct contact, or inhalation through the following:

- o Contact with contaminated soil, sludge, sediment, waste piles, buildings, structures, and/or equipment;
- o Contaminated runoff from the site;
- o Potential use of contaminated groundwater;
- o Contaminated airborne particulate emissions.

Site-specific remedial action objectives should refer to specific sources, contaminants, pathways, and receptors.

5.2 DEVELOPING GENERAL RESPONSE ACTIONS

General response actions for lead battery recycling sites that potentially meet the remedial action objectives have been identified. These actions are media-specific. They include no action, treatment, containment, removal, or any combination of these. Table 17 lists the general response actions and associated remedial technologies proposed in presently available RI/FS studies and RODs according to each contaminated medium found at lead battery recycling sites. A list of contractors/vendors for several specific technologies is given in Table 18.

5.3 DEVELOPMENT AND SCREENING OF TECHNOLOGIES

Feasible remedial alternatives for CERCLA lead battery recycling sites for each medium of concern will now be discussed in detail. (Appendix B [Table B-1] lists these alternatives.) Each technology will also be evaluated for six of the nine evaluation criteria developed by EPA: compliance with ARARs; long-term effectiveness and permanence; reduction of toxicity, mobility, or volume; short-term effectiveness; implementability; and cost. They are not, however, evaluated against overall protection of human health and the environment, state acceptance, and community acceptance (the other three EPA criteria).

Innovative technologies are "those technologies where limited available data on the performance and/or cost inhibit their use for many Superfund types of applications (USEPA, 1991)." Currently, all

**TABLE 17. SUMMARY OF GENERAL RESPONSE ACTIONS AND ASSOCIATED REMEDIAL TECHNOLOGIES
COMMONLY PROPOSED FOR LEAD BATTERY RECYCLING SITES**

Medium	General response action	Remedial technology	Known lead battery sites including the technology
Soil	No action	Environmental monitoring	4
	Treatment	Solidification/stabilization	9
		Soil washing	2
	Soil removal	Excavation and off-site disposal in a RCRA landfill	2
Groundwater	Containment	Capping	3
	No action	Groundwater monitoring	4
	Treatment	Pumping with precipitation/flocculation/sedimentation treatment	3
		Ion medium filtration	1
Waste piles	Treatment	On-site washing with lead recovery	1
	Removal	RCRA landfill	2
	Resource recovery	Recycling	3
Building, structures, and equipment	No action	Boarding up structures	All sites
	Demolition and disposal	Off-site RCRA landfill	3
	Decontamination	Solvent or detergent washing	2
Pits, ponds, lagoons, surface water	Drainage control	Drainage control measures	All sites
	Sediment treatment	Solidification/stabilization	3
	Sediment removal	Mechanical dredging and off-site disposal in a RCRA landfill	1

TABLE 18. CONTRACTOR/VENDOR LIST

Process	Company name, location
Solidification/stabilization	ATW/Caldwell, Sante Fe Springs, CA Bethlehem Steel, Bethlehem, PA Chemfix Technologies, Inc., Metairie, LA Chemical Waste Management, Riverdale, IL Ensight, Inc., Tucker, GA Ensotech, Inc., North Hollywood, CA Envirite Field Services, Plymouth Meeting, PA Geo-Con, Inc., Pittsburgh, PA IM-Tech, Oakwood, TX International Waste Technologies, Wichita, KS Lopat Enterprises, Wanamassa, NJ Maecorp, Inc., Chicago, IL Resource Recovery of America, Inc., Lakeland, FL Separation and Recovery Systems, Inc., Irvine, CA Silicate Technology Corp., Scottsdale, AZ Soliditech, Inc., Houston, TX Solidtek Systems, Inc., Morrow, GA ToxCo, Division of Thorne Environmental, Inc., Anaheim, CA Wastech, Inc., Oak Ridge, TN Westinghouse Hittman Nuclear, Inc., Columbia, MD
Soil washing	Biotrol, Inc., Chaska, MN Chapman, Inc., Atlantic Highlands, NJ Ecova Corporation, Redmond, WA Harmon Environmental Services, Inc., Auburn, AL Ozonics Recycling Corporation, Key Biscayne, FL Waste-Tech Services, Inc., Golden, CO Westinghouse Electric Corporation, Pittsburgh, PA
Acid leaching	Bureau of Mines, Washington, DC
Precipitation/flocculation/ sedimentation	ANDCO Environmental Process, Amherst, NY Carbon Air Services, Hopkins, MN Chemical Waste Management, Riverdale, IL Detox, Inc., Dayton, OH Ensotech, Inc., North Hollywood, CA Envirochem Waste Mgmt. Serv., Cary, NC Rexnord Industries, Milwaukee, WI Tetra Recovery System, Pittsburgh, PA
Recycling	
o Pretreatment	Canonie Environmental Services Corp.
o General	Waste exchanges (PIES Bulletin Board)
o Lead	Smelters (Appendix F)
o Plastic	Battery case manufacturers
o Ebonite	Cement kilns & power plants

Sources: USEPA, 1986b; USEPA, 1986c; USEPA, 1987c; and USEPA, 1990h

source control technologies -- with the exception of immobilization of most inorganics and incineration of most organics -- are innovative. With regard to groundwater remediation, all in situ technologies for remediating groundwater and source material are currently considered innovative. This section will discuss potentially applicable innovative technologies that are either in or selected for the SITE demonstration program. The technologies will be discussed by medium (i.e., for soil: Biotrol, Inc. Soil Washing, Geo Safe In Situ Vitification, in situ solidification/stabilization, Retech, Inc. Plasma Reactor, and Babcock and Wilcox Co. Cyclone Furnace; for groundwater: Bio-Recovery Systems, Inc. Biological Sorption and Colorado School of Mines' Wetlands-Based Treatment; and for waste piles: Horsehead Resource Development Co., Inc. Flame Reactor and Risk Reduction Engineering Laboratory Debris Washing System).

5.3.1 No Action

The no action alternative provides a baseline against which other alternatives can be compared. This alternative contains no remedial action yet it does involve environmental monitoring and institutional restrictions such as site fencing, deed restrictions, restrictions on groundwater usage, warning against excavation, and public awareness programs.

Periodic groundwater monitoring is conducted throughout the area of potential contamination using on-site/off-site monitoring wells and, possibly, nearby residential wells. It evaluates the migration of contaminants and the potential for contamination of nearby residential wells. In addition, sampling of surface water and soil/sediment are conducted to monitor off-site transport of contaminants via surface water runoff, erosion, and fugitive dust.

Advantages:

- o None. However periodic monitoring of groundwater provides a warning mechanism against future contaminant concentrations and possible migration from the site.

Disadvantages:

- o No treatment or engineering control is exercised. Therefore risks due to direct contact, ingestion and inhalation remain.
- o Neither toxicity, mobility, nor volume of contaminants is reduced.
- o There may be a time lag between contaminant migration and detection.

5.3.2 Contaminated Medium: Soil

Overview--

- o The RPM should be aware that no full-scale, innovative technologies have yet been applied at lead battery recycling sites. However, prior to completion of this report, novel (non-cement based) solidification operations to achieve very low allowable leachate levels were planned for sites at Lee's Farm, Wisconsin and Cedartown Battery, Georgia.
- o Cement-based solidification has been most widely used/tested S/S technology.
- o Soil washing/acid leaching -- in particular the BOM process -- shows promise. However, it still remains to be proven in a pilot-scale unit. Its planned implementation at the USL and Arcanum sites in Ohio should provide valuable information on the process.

- o Excavation and off-site disposal has been practiced in the past. However, it will not continue (due to Land Disposal Restrictions), unless the contaminated materials are treated prior to disposal.
- o Capping has been proposed for some sites with low contamination levels.

Lead is the primary contaminant found in soil at lead battery recycling sites. Other heavy metals such as antimony, cadmium, copper, arsenic, and selenium are sometimes present, but normally only in trace concentrations. Lead-contaminated soils are a RCRA characteristic waste if the TCLP lead level is greater than 5.0 mg/L. To ensure protection of personnel and the community, a health-based action level must be developed at lead battery recycling sites.

In accordance with OSWER Directive #9355.4-02, ARARs are not available for lead in soil, and therefore, a soil cleanup range of 500 to 1,000 mg/kg established by the Center for Disease Control (1985) -- based on childhood lead poisoning -- has been adopted as a technical directive (USEPA, 1989c). This OSWER directive is currently undergoing review and may be revised. Different action levels have been implemented at specific sites under varying site conditions. (See Table 6.)

Sediments and sludges from pits, ponds, lagoons, and surface water are generally treated with contaminated soils at lead battery recycling sites.

5.3.2.1 Solidification/Stabilization of Soil (S/S)--

Solidification processes produce monolithic blocks of waste with high structural integrity. The contaminants do not necessarily interact chemically with the solidification reagents (typically cement/lime) but are mechanically locked within the solidified matrix. Stabilization methods usually involve the addition of materials such as fly ash or blast furnace slag which limit the solubility or mobility of waste constituents -- even though the physical handling characteristics of the waste may not be changed or improved (USEPA, 1982). Methods involving S/S techniques are often proposed in RODs and RI/FSs for lead battery recycling sites. Solidification/stabilization of contaminated soil can be conducted either in situ or ex situ. In situ S/S techniques are now considered innovative and are discussed later in this section.

Usually S/S encompasses excavating the surface and subsurface soils contaminated with lead and treating them with a pozzolanic stabilization process. If the treated soil no longer displays the TCLP toxicity characteristic for lead, it can be deposited off-site in a local industrial or sanitary landfill or in an on-site landfill. If the treated soil complies with RCRA land disposal restrictions [40 CFR 268], it can be deposited in a RCRA landfill.

The most common processes used at lead battery recycling sites employ portland cement or lime pozzolans. S/S involves mixing the contaminated soil with portland cement and/or lime along with other binders such as fly ash or silicate reagents to produce a strong, monolithic mass. Cement is generally suitable for immobilizing metals (such as lead, antimony, cadmium, and nickel) which are found at lead battery recycling sites. Because the pH of the cement mixture is high (approximately 12), most multivalent cations are converted into insoluble hydroxides or carbonates. They are then resistant to leaching. Arsenic does not form insoluble hydroxides or carbonates. Some metals like lead, nickel, etc. have increased solubility at the very high pHs that occur in the cement hydration reaction. For example, during the S/S processing of lead with cement, the lead is most likely converted into its least soluble form, namely lead hydroxide ($\text{Pb}(\text{OH})_2$). On the other hand, when a weak acid-slurry salt such as sodium silicate (Na_2SiO_3) is added, the salt undergoes hydrolysis and increases the OH^- concentration drastically. This results in the formation of PbO_2^{2-} which can leach out easily. Therefore, pH is the

key process variable to control (Barth et al, 1990). This effect is important when highly alkaline binders are used. However, metal hydroxides and carbonates are insoluble only over a narrow pH range; they are subject to leaching and solubilization in the presence of even mildly acidic leaching solutions, such as rain (USEPA, 1985c). Therefore, the solidified waste must be capped or deposited in a landfill. S/S increases the weight and volume of the original material from 10 to 100%, thereby increasing transportation and disposal costs. The actual increase in volume should be verified during treatability studies.

Critical parameters in stabilization treatment include the selection of stabilizing agents and other additives, the waste-to-additive ratio, and the mixing and curing conditions. All these parameters depend on the chemical and physical characteristics of the waste. Bench-scale treatability tests are required to select the proper additives ratios and curing times. Leaching and compressive strength tests determine the integrity of the end product. Numerous leaching tests have been developed to test solid wastes, including the American Nuclear Society leach tests (ANS 16.1), and the Dynamic Leach Test (DLT) developed especially for hazardous wastes. More detail can be obtained from *Stabilization/Solidification of CERCLA and RCRA Wastes: Physical Tests, Chemical Testing Procedures, Technology Screening, and Field Activities* (USEPA, 1989a).

Advantages:

- o It reduces the migration of lead.
- o Treatment is relatively inexpensive.
- o Solid product can be prepared by careful selection of material.
- o Mixing equipment is readily available.
- o Technology is suitable for immobilizing heavy metals, such as lead at lead battery recycling sites.
- o Additives are readily available.

Disadvantages:

- o It increases volume of treated material.

Problems and Concerns:

- o Secondary containment may be needed because lead, still present, may migrate with time. No long-term data is available at this time.
- o Undesirable chemical reactions can occur. Material compatibility must be investigated.
- o Large amounts of dissolved sulfate salts or metallic anions in wastes (e.g., arsenates and borates) hamper solidification and concrete stability.
- o Organic matter, lignite, silt, or clay in wastes increases setting time and can lead to materials handling and mixing complications.
- o Oil and grease interfere with bonding by coating the waste particles.

TABLE 19. SUMMARY OF EPA EVALUATION CRITERIA OF REMEDIAL TECHNOLOGIES FOR SOIL

Remedial technology	Compliance with ARARs	Long-term effectiveness and permanence	Reduction of toxicity, mobility, or volume	Short-term effectiveness	Implementability	Cost
No action	Does not comply with RCRA clean closure or landfill closure requirements [40 CFR Part 264, Subpart G].	Contaminants would continue to migrate off-site and downward through subsurface soil. Groundwater monitoring would determine degree of contaminant leaching and provide a warning mechanism.	Does not reduce toxicity, mobility, or volume of contamination in the soil.	Remedial action not involved. Protection of workers, community, and environment during remediation activities is not a consideration. Minimal protection of public health from exposure to on-site surface soils.	No implementability considerations. Would not interfere with future remedial actions.	No capital costs. There will be costs associated with sampling and analysis.
Solidification/stabilization	Must comply with NAAQ Standards for lead and particulate matter. Worker protection during on-site activities must comply with OSHA health and safety requirements. Must comply with RCRA closure requirements under 40 CFR Part 264, Subpart G. Off-site or on-site disposal must comply with RCRA land disposal restrictions [40 CFR Part 268]. Off-site transportation must comply with <ul style="list-style-type: none">o RCRA hazardous waste generator and transportation regulations,o Federal and state DOT transportation regulations.	No long-term human health or environmental risks would be anticipated with site (data on long-term effectiveness of solidification is limited).	Increases volume of contaminated soil (approximately 10-100%). Reduces the mobility of lead in the soil.	Dust may be generated during excavation and handling activities. Respiratory protection, fugitive dust control procedures, and air monitoring may be required to protect workers and community.	Widely implemented and reliable. Large staging area required. Many vendors, mobile systems available for processing excavated soil. Would not interfere with future remedial actions at site. Presence of interfering compounds may inhibit solidification process.	\$27-\$164/cu yd ² (USEPA, 1988a).

TABLE 19. (continued)

Remedial technology	Compliance with ARARs	Long-term effectiveness and permanence	Reduction of toxicity, mobility, or volume	Short-term effectiveness	Implementability	Cost
Solidification/stabilization (continued)	On-site treatment must comply with RCRA and state operating regulations.					
Soil washing/acid leaching	<p>If treated soil is shipped to a sanitary/industrial waste landfill, the facility must comply with RCRA and state regulations.</p> <p>Must comply with NAAQ standards for lead and particulate matter.</p> <p>Worker protection during on-site activities must comply with OSHA health and safety requirements.</p> <p>Must comply with RCRA closure requirements under 40 CFR Part 264, Subpart G.</p> <p>On-site treatment must comply with RCRA and state operations regulations.</p> <p>On-site or off-site disposal must comply with RCRA land disposal restrictions (40 CFR Part 268).</p>	<p>No long-term human health or environmental risks would be associated with site.</p> <p>Groundwater monitoring not required.</p>	<p>Permanently reduces toxicity of soil by removing lead.</p> <p>Concentrates contaminants into much smaller volume.</p> <p>In order to reduce volume, process must provide a satisfactory method for treating washing fluids.</p>	<p>Dust may be generated during excavation and handling activities.</p> <p>Respiratory protection, fugitive dust control procedures, and air monitoring may be required to protect workers and community.</p>	<p>Bench- and pilot-scale testing required to assess all implementability considerations.</p> <p>No mobile systems available; treatment plant must be constructed on-site.</p> <p>Large staging area required.</p>	<p>\$208/cu yd^a (Schmidt, 1989).</p> <p>Value of recovered metal can partially offset treatment costs.</p>
Excavation and off-site disposal	<p>Must comply with NAAQ standards for lead and particulate matter.</p> <p>Worker protection during on-site activities must comply with OSHA health and safety requirements.</p> <p>Off-site transportation must comply with</p>	<p>No long-term human health or environmental risks would be associated with site.</p> <p>Groundwater monitoring not required.</p>	<p>Does not reduce toxicity or volume of contaminants in the soil. Mobility is reduced by placing them in a RCRA-landfill.</p>	<p>Dust may be generated during excavation and handling activities. Respiratory protection, fugitive dust control procedures, and air monitoring may be required to protect workers and community.</p>	<p>Technologies are demonstrated and commercially available.</p> <p>Land disposal restrictions apply.</p> <p>Would not interfere with future remediation actions at site.</p>	<p>\$267-488 cu yd^a (1982) (Environmental Law Institute, 1984).</p>

TABLE 19. (continued)

Remedial technology	Compliance with ARARs	Long-term effectiveness and permanence	Reduction of toxicity, mobility, or volume	Short-term effectiveness	Implementability	Cost
Excavation and off-site disposal (continued)	<ul style="list-style-type: none"> o RCRA hazardous waste generator and transportation regulations, o Federal and State DOT transportation regulations <p>The disposal facilities must comply with RCRA and state regulations for disposal.</p>					
Capping	<p>Must comply with NAAQ standards for lead and particulate matter.</p> <p>Worker protection during on-site activities must comply with OSHA health and safety requirements.</p> <p>Must comply with RCRA closure requirements under 40 CFR Part 264, Subpart G.</p>	<p>Capping provides protection of public health from exposure to on-site soil contamination and controls off-site migrations of contaminants.</p> <p>Groundwater monitoring required to verify that no leaching of contaminants occurs at downgradient locations.</p>	<p>Does not reduce toxicity or volume of contamination at the site.</p> <p>Reduces downward mobility of contaminants and reduces off-site migration of contaminants due to wind erosion and surface water run-off.</p>	<p>Dust may be generated during excavation and handling activities. Respiratory protection, fugitive dust control procedures, and air monitoring may be required to protect workers and community.</p>	<p>Readily Implemented.</p> <p>Technologies are reliable and commercially available.</p> <p>Future remedial actions required removal of cap and disposal of cap materials if caps is not reinstalled.</p>	<p>\$6.06/sq ft^a for a multi-layered cap (USEPA, 1985b). Cost varies with the type of cap.</p>

^aUpdated to 1990 using cost indexes in Engineerings News Record.

Successful S/S of soil would achieve a remedial action objective by protecting the public health from ingestion and inhalation of contaminated soil, and by inhibiting the migration of lead and other contaminants to groundwater and off-site. This technology is a RCRA Land Disposal Restriction Best Demonstrated Available Technology (BDAT) to treat lead-contaminated wastes (D008 wastes). Table 19 summarizes the EPA evaluation criteria for technologies that remediate soil used at sites with completed RI/FS or RODs.

Two specific in situ S/S techniques, studied under the SITE Program, hold promise for lead battery recycling sites.

International Waste Technologies/Geo-Con, Inc. In Situ Solidification/Stabilization Process--This in situ solidification/stabilization technology immobilizes organic and inorganic compounds in wet or dry soils, using additives to produce a cement-like mass. The basic components of this technology are: Geo-Con's deep soil mixing system (DSM) which delivers and mixes the chemicals with the soil in situ; and a batch mixing plant to supply the International Waste Technologies (IWT) proprietary treatment chemicals.

The IWT technology can be applied to soils, sediments, and sludges contaminated with organic compounds and metals. The technology has been laboratory-tested on soils containing pentachlorophenol (PCP), polychlorinated biphenyls (PCBs), refinery wastes, and chlorinated or nitrated hydrocarbons.

The DSM system can be used in almost any soil type. However, mixing time increases in proportion with fines. It can be used below the water table and in soft rock formations. Large obstructions must be avoided. The SITE Demonstration of this technology occurred in April, 1988.

S.M.W. Seiko, Inc. In Situ Solidification/Stabilization--The Soil-Cement Mixing Wall (S.M.W.) technology developed by Seiko, Inc. involves the in situ stabilization and solidification of contaminated soils. Multi-axis, overlapping, hollow-stem augers are used to inject solidification/stabilization agents and blend them with contaminated soils in situ. The product is a monolithic block down to the treatment depth. This technology applies to soils contaminated with metals and semi-volatile organic compounds. This project was accepted into the SITE Demonstration Program in June 1989. Site selection is currently underway.

5.3.2.2 Soil Washing/Acid Leaching--

Soil washing is a water-based process for mechanically scrubbing soils ex situ to remove undesirable contaminants. The process removes contaminants from soils in one of two ways: by dissolving or suspending them in the wash solution or by concentrating them into a smaller volume of soil through simple particle size separation techniques. Acid leaching dissolves contaminants by lowering the pH of the system.

This technology excavates the lead-contaminated soil, washing the lead on-site with a solution (such as nitric acid or EDTA), and returning the treated soil to the site for disposal in the excavation area. There is limited field experience with the washing of excavated soil at lead battery recycling sites. (See Section 4.1.2.) EDTA was used as part of an EPA emergency response at Lee's farm in Wisconsin with less than satisfactory results due to materials handling and other process-related problems, such as wastewater treatment, filtering of the sand and silts, incompatibility of processing equipment with EDTA (Weston-Sper, 1988). Bench-scale treatability studies performed at three lead battery recycling sites (C&R Battery, VA; and United Scrap Lead and Arcanum, OH) by the U.S. Bureau of Mines showed high removal efficiencies for lead using nitric acid. One of the limitations of soil washing as a viable alternative concerns the physical nature of the soil. Soils which are high in clay, silt, or fines have

proven difficult to treat. Bench-and pilot-scale testing must be performed prior to implementation. This technology requires significant development. It is classified as emerging or innovative in the United States. Nevertheless, it is used extensively in Europe. More details on non-U.S. processes can be obtained from *Treatment Technology Bulletin: Soil Washing* (USEPA, 1990c). This document is currently in draft form, with final edition expected in 1991.

Figure 3 describes the U.S. Bureau of Mines Acid Leaching Process. Fine soil is subjected to a carbonation step, using ammonium carbonate solution. Ammonium bisulfite (NH_4HSO_3) is also added to convert PbO_2 in the soil to PbSO_4 ; the PbSO_4 is, in turn, converted to PbCO_3 by the ammonium carbonate ($(\text{NH}_4)_2\text{CO}_3$). The mix is heated and agitated to precipitate the lead as acid-soluble lead carbonate. The carbonated soil is washed in a nitric acid solution to solubilize the lead carbonate. The mix is filtered, rinsed, and conveyed to acid soak tanks where lead sulfate is precipitated by sulfuric acid (Schmidt, 1989). There is a market for lead sulfate. The clean soil is stored or returned to the site. Waste streams from the washing system require further treatment before final discharge. Some active lead battery recycling sites have on-site industrial wastewater treatment systems that may be able to receive these waste streams.

Bench- and laboratory-scale treatability tests, as discussed in Section 4, would determine the type of washing solution, optimum concentration, optimum reaction time, potential methods of regeneration, and other wastewater treatment requirements. Soil washing produces large amounts of contaminated water requiring treatment.

Advantages:

- o Volume of the contaminant mass is reduced.
- o Recyclable lead product from acid leaching can partially offset the cost of treatment.

Disadvantages:

- o Soil washing and acid leaching are still in the bench-scale development stage.
- o Soils which are high in clay, silt, and/or humic material have proven difficult to treat.
- o Workers must be trained to handle acids for the acid leaching process.
- o Specialized acid-resistant equipment must be used for the acid leaching process.

Problems and Concerns:

- o Mineralogical characteristics of soil and previous soil treatment (e.g., neutralization) can have detrimental effects on process reactions and usage of reagents.
- o Laboratory and pilot testing are necessary to determine feasibility.
- o Effluent from soil washing systems require further treatment before final discharge. If reagents are expensive and are not recyclable, they will increase treatment costs.
- o Lead sulfate sludge may require further treatment before sale.

Figure 3. Bureau of Mines Soil Washing Process

Biotrol, Inc. Soil Washing--The Biotrol Soil Washing System is a water-based, volume-reduction process for treating excavated soil. The objective of this process is to concentrate the contaminants in a smaller volume of material separate from a washed soil product. The efficiency of soil washing can be improved using surfactants, detergents, chelating agents, pH adjustment, or heat. This technology is applicable to soils contaminated with polyaromatic hydrocarbons (PAHs), PCP, pesticides, PCBs, various industrial chemicals, and metals. This process was demonstrated under the SITE program in 1989 for soil contaminated with PCP and PAHs from the MacGillis & Gibbs Superfund Site in New Brighton, Minnesota.

5.3.2.3 Soil Excavation and Off-Site Disposal

Excavation and removal of contaminated soil to a RCRA landfill, have been performed extensively at lead battery recycling sites. Off-site disposal must be done in a RCRA landfill. Landfilling of hazardous materials is becoming increasingly difficult and expensive due to growing regulatory control.

Excavation and removal are applicable to almost all site conditions, although they may be cost-prohibitive for sites with large volumes, greater depths or complex hydrogeologic environments. Determining the feasibility of off-site disposal requires knowledge of land disposal restrictions (See Section 2.4) and other regulations developed by state governments. Excavation can be accomplished by a wide variety of conventional equipment such as backhoes, cranes, draglines, clamshells, dozers, and loaders. The hauling equipment includes scrapers, haulers, dredges, dozers, and loaders. Fugitive dusts from excavation are commonly controlled by chemical dust suppressants, wind screens, water spraying, and other dust control measures (e.g., maintaining a favorable slope).

Advantages:

- o Engineering control is achieved.
- o Contamination is eliminated at the site.
- o There is no need for long-term monitoring.
- o It is capable of combination with almost any other remedial technology.

Disadvantages:

- o Costs associated with off-site disposal are high.
- o Short-term impacts such as fugitive dust emissions are a major concern.
- o Contamination is transferred to another location.

Problems and Concerns:

- o The location of the RCRA-compliant landfill, to which the excavated soil would be transported, has a substantial impact on cost.
- o Without treatment, this technology may not meet RCRA land disposal restrictions.

5.3.2.4 Soil Capping--

Capping involves the installation of an impermeable barrier over the contaminated soil to restrict access and reduce infiltration of water into the soil. A variety of cap designs and materials are available. Most designs are multi-layered to conform with the performance standards in 40 CFR 264.310 which addresses RCRA landfill closure requirements. However, single-layered designs are used for special purposes at lead battery recycling sites, for example, when treated soil is backfilled into an excavated area. Low permeability clays and synthetic membranes are commonly used. They can be covered with top soil and vegetated to protect them from weathering and erosion. Soil materials are readily available, and synthetic materials are widely manufactured and distributed.

The selection of capping materials and a cap design are influenced by specific factors such as local availability and cost of cover materials, functions of these materials, the nature of the waste being covered, local climate, site hydrogeology, and the projected future use of the site.

There are two basic capping designs: multi-layered and single-layered. The RCRA land disposal regulations of 40 CFR, Subparts K through N require multi-layered caps. The statute describes the proper design: a three-layered system consisting of 1) a low permeability layer, 2) a drainage layer, and 3) an upper vegetative layer (USEPA, 1985b).

For the first 20 years of service, a properly installed cap generally performs well. However, it should be inspected on a regular basis for signs of erosion, settlement, or subsidence -- and restored as necessary. In addition, associated groundwater monitoring wells must be maintained and sampled periodically.

Advantages:

- o Engineering control (containment) is achieved.
- o It presents a more economical alternative than excavation and removal of wastes.
- o The technology reliably seals off contamination.
- o Soil materials are readily available.
- o Synthetic materials are widely manufactured and distributed.

Disadvantages:

- o It does not remove contamination.
- o It establishes need for long-term maintenance.
- o Design life is uncertain.
- o Long-term monitoring is required.

Problems and Concerns:

- o Periodic inspection and maintenance (i.e., mowing, reseeding, resealing) are needed to assure a cap's long-term integrity.

The cost of a cap depends on the type and amount of materials selected, the thickness of each layer, and the region. Table 20 presents the general material and installation costs for caps larger than 10 acres. In a recent RCRA Part B permit application for a 4-acre hazardous waste landfill, the installed cost of a multi-layered cap was estimated at \$5.45/ft². The design for this cap included 3 ft of top soil, overlying a 1-ft sand layer, overlying 1 ft of compacted clay, overlying a 30-mil High Density Polyethylene (HDPE) liner, overlying 2 ft of compacted clay (USEPA, 1985b).

5.3.2.5 In Situ Vitrification--

Contaminated soils are converted into chemically inert, stable glass and crystalline materials by a thermal treatment process. Large electrodes are inserted into soil containing significant levels of silicates. Because soil typically has low conductivity, flaked graphite and glass frit are placed on the soil surface between the electrodes to provide a starter path for electric current. A high current passes through the electrodes and graphite. The heat melts contaminants, gradually working downward through the soil. Volatile compounds are collected at the surface for treatment. After the process ends and the soil has cooled, the waste material remains fused in a chemically inert and crystalline form that has very low leachability rates. This process can be used to remove organics and/or immobilize inorganics in contaminated soils or sludges. It has not yet been applied at a Superfund site. However, it has been field demonstrated on radioactive wastes at the DOE's Hanford Nuclear Reservation by the Geosafe Corporation.

Advantages:

- o Technology is suitable for immobilizing heavy metals.
- o Resulting vitrified mass is effectively inert and impermeable.

Disadvantages:

- o The process is energy intensive and often requires temperatures up to 2500°F for fusion and melting of the waste matrix.
- o Special equipment and trained personnel are required.
- o The technology has not been demonstrated for heavy metals yet.

Problems and Concerns:

- o Water in the soil affects operational time and increases the total costs of the process.
- o The technology has the potential to cause some contaminants to volatilize and migrate to the outside boundaries of the treatment area.

5.3.2.6 Other Innovative Processes--

Retech, Inc. Plasma Reactor--This thermal treatment technology uses heat from a plasma torch to create a molten bath that detoxifies contaminants in soil. Organic contaminants vaporize and react at very high temperatures to form innocuous products. Solids melt into the molten bath. Metals remain in this phase, which -- when cooled -- forms a non-leachable matrix.

TABLE 20. 1990 UNIT COSTS ASSOCIATED WITH CAPPING DISPOSAL SITES

Element	Cost ^a
Clearing and grubbing	\$1,227.00/acre
Excavation	\$1.78/yd ³
Earthfill	
Berms and levees	\$2.34/yd ³
Soil liners	\$3.46/yd ³
Backfill	\$3.46/yd ³
Soil import	
Drainage sand	\$11.71/yd ³
Drainage rock (rounded)	\$11.71/yd ³
Soil placement	\$1.12/yd ³
Vegetation, mulch, and hydroseed	\$1,227.00/acre
Geotextile fabrics	\$1.12 - \$3.46/yd ²
Bentonite admix (2-9 lbs/yd ³) ^b	\$0.22 - \$1.23/ft ²
Membrane liners	
Nonreinforced	
30 mil PVC	\$0.28 - \$0.39/ft ²
30 mil CPE	\$0.39 - \$0.50/ft ²
30 mil Butyl/EPDM	\$0.50 - \$0.61/ft ²
30 mil Neoprene	\$0.78 - \$0.89/ft ²
100 mil HDPE	\$1.23 - \$1.78/ft ²
Reinforced	
36 mil Hypalon (CSPER)	\$0.56 - \$0.67/ft ²
60 mil Hypalon (CSPER)	\$0.89 - \$1.12/ft ²
36 mil Hypalon	\$0.56 - \$0.67/ft ²
Installation, excluding earthwork	\$0.67 - \$1.34/ft ²

^aBased on costs for a 400,000 ft² area (USEPA, 1985b) as updated by construction, labor, and material cost indices in Engineering News Record 1985 and 1990.

^bIncludes mixing and placing.

PVC - polyvinyl chloride

CPE - chlorinated polyethylene

EPDM - ethylene-propylene-diene-monomer

CSPER - chlorosulfonated polyethylene (reinforced)

This technology can treat both liquid and solid organic compounds. It is most appropriate for soils and sludges contaminated with metals and hard-to-destroy organic compounds. A demonstration is planned in late 1990 at a Department of Energy research facility in Butte, Montana.

Babcock and Wilcox Co. Cyclone Furnace Process--This cyclone furnace technology is designed to decontaminate wastes containing both organic and metal contaminants. The cyclone furnace retains heavy metals in a non-leachable slag and vaporizes organic materials prior to incinerating them.

The treated soils resemble natural obsidian (volcanic glass), similar to the final product of vitrification.

This technology is applicable to solids and soil contaminated with organic compounds and metals. Babcock and Wilcox are developing this process under the SITE Emerging Technologies Program.

5.3.3 Contaminated Medium: Groundwater--

Treatments using precipitation/flocculation/sedimentation and ion exchange are often considered for remediation of lead battery recycling sites.

Groundwater contamination at lead battery recycling sites is primarily caused by lead and other heavy metals such as cadmium, chromium, arsenic, and antimony. Very often the levels of these contaminants are below detection limits. Lead contamination above 15 $\mu\text{g/L}$ in groundwater is considered a health threat. Groundwater treatments such as precipitation/flocculation/sedimentation, ion exchange, and ion medium filtration have been recommended in RODs and RI/FSs. Ion medium filtration, referred to as the "metal grabber" process, is based on passing metal-contaminated water through a medium that selectively binds cations. Unlike an ion exchange bed, the unit is a disposable canister containing a granular solid medium instead of a regenerable resin. Ion medium filtration is still in pilot-scale development (Woodward-Clyde Consultants, 1988); therefore, it will not be further discussed as an available remedy.

Contaminated water from pits, ponds, and lagoons is typically pumped and treated together with groundwater.

Contaminated groundwater can be treated on-site and then discharged either to a publicly owned treatment works (POTW), to a surface water body, or into the ground. Some active lead battery recycling sites may have on-site industrial wastewater treatment systems that can receive groundwater. A NPDES permit would be required for surface water discharge. Table 21 summarizes EPA evaluation criteria of remedial alternatives for groundwater.

5.3.3.1 Precipitation/Flocculation/Sedimentation--

The combination of precipitation/flocculation/sedimentation is a well-established technology with specific operating parameters for metals removal from groundwater. This technology pumps groundwater through extraction wells and then treats it to precipitate lead and other heavy metals. Typical removal of metals employs precipitation with hydroxides, carbonates, or sulfides. Hydroxide precipitation with lime is the most common choice. Generally lime, soda ash, or sodium sulfide is added to water in a rapid-mixing tank along with flocculating agents such as alum, lime, and various iron salts. This mixture then flows to a flocculation chamber that agglomerates particles, which are then separated from the liquid phase in a sedimentation chamber. Other physical processes, such as filtration, may

TABLE 21. SUMMARY OF EPA EVALUATION CRITERIA OF REMEDIAL TECHNOLOGIES FOR GROUNDWATER

Remedial technology	Compliance with ARARs	Long-term effectiveness and permanence	Reduction of toxicity, mobility, or volume	Short-term effectiveness	Implementability	Cost
No action	Does not comply with RCRA clean closure or landfill closure requirements [40 CFR Part 264, Subpart G].	Contaminants would continue to migrate off-site and downward through subsurface soil. Groundwater monitoring would determine degree of contaminant leaching and provide a warning mechanism.	Does not reduce toxicity, mobility, or volume of contamination in the groundwater.	No remedial action involved, so protection of workers, community, and environment during remediation activities is not a consideration. Minimal protection of public health from exposure to on-site groundwater.	No implementability considerations. Would not interfere with future remedial actions.	No capital costs. There will be costs associated with sampling and analysis.
Treatment using precipitation/flocculation/sedimentation	Complies with chemical-specific and action-specific ARARs On-site surface water discharge must comply with the NPDES regulations. Reinjection of treated water into the ground must comply with Federal MCL or applicable state laws.	No long-term human health or environmental risks would be associated with the site.	Permanently reduces toxicity and volume of contaminants.	Dust may be generated during excavation and handling activities. Respiratory protection, fugitive dust control procedures, and air monitoring may be required to protect workers and community	Technologies are well demonstrated and commercially available. Would not interfere with future remedial actions at site.	Equipment rental ranges from \$5,492 to \$27,482/month ^a depending on the flow rate. (USEPA, 1986b)
Treatment using ion exchange	Complies with chemical-specific and action-specific ARARs On-site surface water discharge must comply with the NPDES regulations. Reinjection of treated water into the ground must comply with Federal MCL or applicable state laws.	No long-term human health or environmental risks would be associated with the site.	Permanently reduces toxicity and volume of contaminants.	Dust may be generated during site activities. Respiratory protection, fugitive dust control procedures, and air monitoring may be required to protect workers and community.	Technologies are well demonstrated and commercially available. Would not interfere with future remedial actions at site.	Ion exchange system servicing a flow of 50 gpm required an initial capital investment of \$91,650 ^a and an annual operation and maintenance cost of \$15,850 ^a (USEPA, 1986b).

^aUpdated to 1990 using cost indexes in Engineering News Record.

follow. Metal sulfides exhibit significantly lower solubility than their hydroxide counterparts, achieve more complete precipitation, and provide stability over a broad pH range (Figure 4). At a pH of 4.5, sulfide precipitation can achieve the EPA-recommended standard for potable water (i.e., 15 $\mu\text{g/L}$). Sulfide precipitation -- often effective -- can be considerably more expensive than hydroxide precipitation, due to higher chemical costs and increased process complexity. The precipitated solids would then be handled in a manner similar to contaminated soils. The supernatant would be discharged to a nearby stream or to a POTW.

Selection of the most suitable precipitate or flocculant, optimum pH, rapid mix requirements, and most efficient dosages is determined through laboratory jar test studies.

Groundwater pumping and treatment would require a longer time span -- depending on the surface area of the contaminated aquifer, its porosity, and its hydraulic conductivity. Models can estimate the time required to restore the water in a contaminated aquifer to a desired cleanup level for a given chemical (USEPA, 1990g). At Western Processing in Kent, Washington, a feasibility study concluded that the pumping and treating process would take up to 120 years (CH2M Hill, 1985); at the Sapp Battery Site, Florida, it would take only 7 years (Ecology and Environment, 1987).

Advantages:

- o Treatment of contaminated groundwater is achieved.
- o Technologies are well established.
- o Operating parameters have been defined.
- o Equipment is readily available and easy to operate.
- o This process can be easily integrated into more complex treatment systems.

Disadvantages:

- o Sludge must be sent for proper disposal.
- o This technology requires a relatively longer time period.

Problems and Concerns:

- o Sludge residues may be hazardous; they may require further treatment before disposal.

5.3.3.2 Ion Exchange--

Ion exchange is a process whereby the toxic ions are removed from the aqueous phase in an exchange with relatively harmless ions held by the ion exchange material. Modern ion exchange resins consist of synthetic organic materials containing ionic functional groups to which exchangeable ions are attached. These synthetic resins are structurally stable and exhibit a high exchange capacity. They can be tailored to show selectivity towards specific ions. The exchange reaction is reversible and concentration-dependent; the exchange resins are regenerable for reuse. All metallic elements -- when present as soluble species, either anionic or cationic -- can be removed by ion exchange.

A practical upper concentration limit for ion exchange is about 2,500 to 4,000 mg/L. A higher

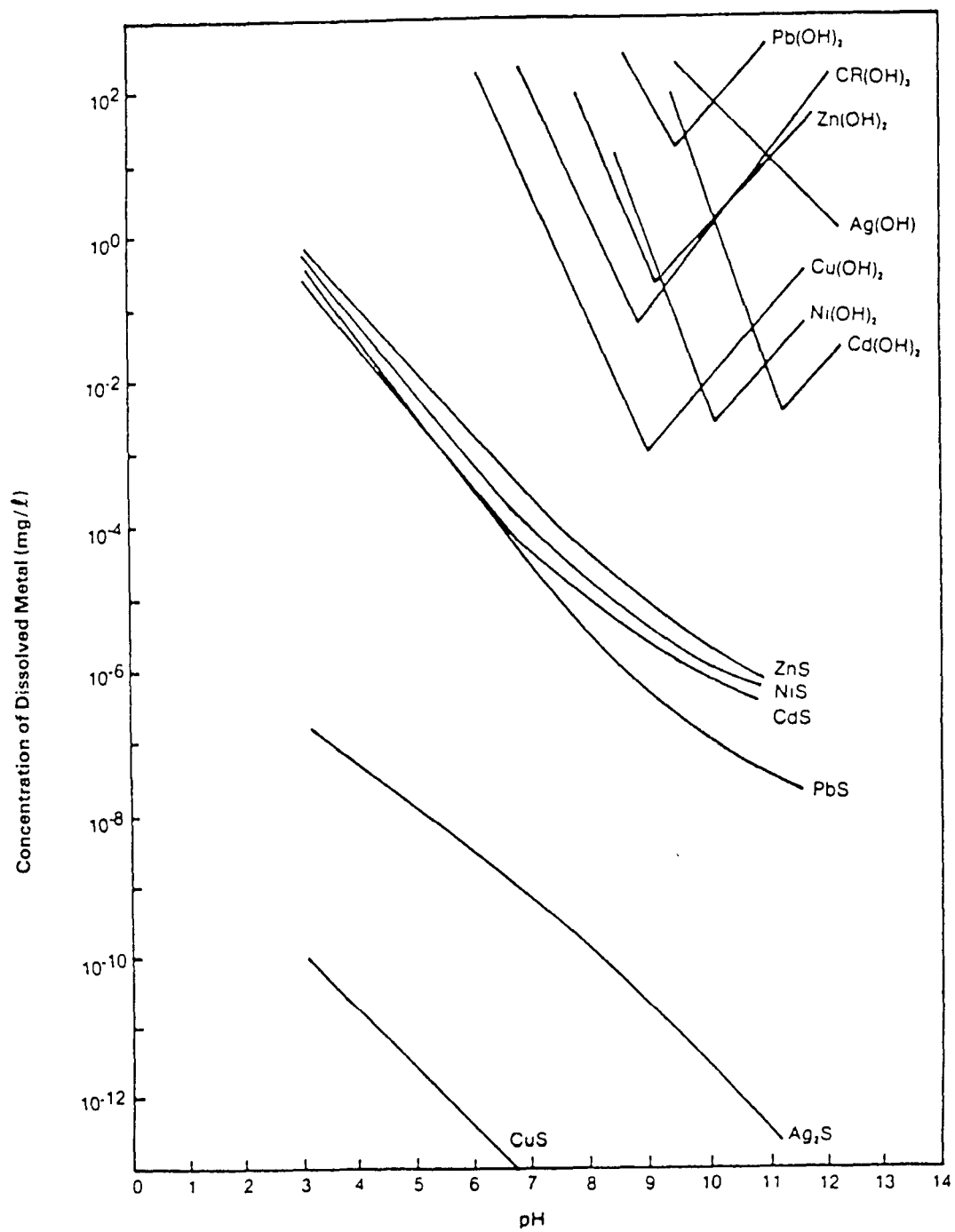


Figure 4. Solubility of metal hydroxides and sulfides

Source: Ghassemi, et al, 1981

concentration results in rapid exhaustion of the resin and inordinately high regeneration costs.

Suspended solids in the feed stream should contain less than 50 mg/L to prevent plugging the resins. Specific ion exchange systems must be designed on a case-by-case basis (USEPA, 1986b).

Advantages:

- o Technologies are well established.
- o Ion exchange systems are commercially available.
- o Units are relatively compact and not energy intensive.

Disadvantages:

- o Technology requires a skilled operator.

Problems and Concerns:

- o Solution used to regenerate contaminated exchange resins must be sent for proper disposal via posttreatment.
- o Regenerating chemical must be compatible with the waste being treated.
- o Resins must be regenerated.
- o Spent resin containing contaminant (e.g., lead) requires RCRA disposal.

5.3.3.3 Other Innovative Processes--

The Bio-Recovery Systems, Inc. Biological Sorption Process--Bio-Recovery Systems, Inc. in Las Cruces, New Mexico is testing AlgaSORB[®], a new technology for the removal and recovery of heavy metal ions from groundwater. This biological sorption process is based on the affinity of algae cell walls for heavy metal ions. This technology is being tested for the removal of metal ions that are "hard" or contain high levels of dissolved solids from groundwater or surface leachates. This process can remove heavy metals including lead. This process is being developed under the SITE Emerging Technologies Program.

Colorado School of Mines' Wetlands-Based Treatment--This wetlands-based treatment uses natural biological and geochemical processes inherent in man-made wetlands to accumulate and remove metals from contaminated water. The treatment system incorporates principal ecosystem components from wetlands, such as organic soils, microbial fauna, algae, and vascular plants.

Waters contaminated with high metal concentrations and have a low pH flow through the aerobic and anaerobic zones of the wetland ecosystem. The metals can be removed by filtration, ion exchange, adsorption, absorption, and precipitation through geochemical and microbial oxidation and reduction.

The Colorado School of Mines has entered this process in the SITE Emerging Technologies Program.

5.3.4 Contaminated Medium: Waste Piles

Waste pile removal and off-site disposal have been practiced in the past but probably will not continue due to Land Disposal Restrictions (LDRs), unless the materials are treated prior to disposal.

Recycling of waste piles, in particular the process developed by Canonie Environmental and sponsored by NL Industries for the Gould Site shows promise. However, it still remains to be proven in a field-scale unit.

Waste piles at lead battery recycling sites are usually by-products from recycling operations. These waste piles can be broken down into several components: battery casings (made of hard rubber, ebonite, or polypropylene), battery internal components, matte (a metallic sulfide waste containing iron and lead), slag, and contaminated debris (see Appendix B). They are contaminated with lead and other heavy metals such as cadmium, chromium, antimony, and arsenic.

Four alternatives are considered as treatments in presently available RODs and RI/FSs: no action, washing, recycling, and removal for off-site disposal. Recycling separates the primary source materials into lead fines, plastics, ebonite, and sludge. Lead fines are potentially marketable. Plastic can be recycled; battery case manufacturers already use this product. Although ebonite has no current market, it has been previously used in other applications such as in fence posts, oil-drilling liquids, asphalt aggregate, and lead smelter fuel. The possibility of using ebonite from the Gould Site as fuel for cement kilns or coal-burning power plants is currently being assessed. A lead smelter can be used to recover lead from sludge. Smelter feed requires lead content of at least 27%. Appendix F lists the primary and secondary lead smelters in the U.S. Table 22 summarizes EPA evaluation criteria of remedial technologies for waste piles.

5.3.4.1 Waste Pile Removal and Off-Site Disposal--

The combination of waste pile removal and off-site disposal encompasses excavation, removal, transportation, and disposal off-site -- in a RCRA-compliant landfill. The RCRA-compliant landfill must meet all regulatory requirements for isolation of contaminated materials from the environment through the use of impervious liners, clays, and other RCRA design features. Landfilling of hazardous materials is becoming increasingly difficult and expensive due to growing regulatory control. LDRs now require treatment of waste to reduce lead in TCLP leachate below 5 mg/L (or to the level prescribed in a treatability variance) prior to disposal. The technologies proposed for excavation and off-site disposal have been demonstrated; they are commercially available. Excavation and removal can totally eliminate both contamination at a site and the need for long-term monitoring.

Advantages:

- o This remedy eliminates the contamination at the site.
- o There is no need for long-term monitoring.
- o Treatment can be used in combination with other remedial technologies.

TABLE 22. SUMMARY OF EPA EVALUATION CRITERIA OF REMEDIAL TECHNOLOGIES FOR WASTE PILES

Remedial technology	Compliance with ARARs	Long-term effectiveness and permanence	Reduction of toxicity, mobility, or volume	Short-term effectiveness	Implementability	Cost
Removal and off-site disposal	<p>Must comply with NAAQ standards for lead and particulate matter.</p> <p>Worker protection during on-site activities must comply with OSHA health and safety requirements.</p> <p>Must comply with RCRA closure requirements under 40 CFR Part 264, Subpart G.</p> <p>Off-site disposal must comply with LDRs (40 CFR Part 268).</p> <p>Off-site transportation must comply with the following:</p> <ul style="list-style-type: none"> o RCRA hazardous waste generator and transportation regulations, o Federal and state DOT transportation regulations <p>The disposal facilities must comply with RCRA and state regulations for disposal.</p>	No long-term human health or environmental risk would be associated with the site.	Does not reduce toxicity or volume of contamination in the waste piles.	Dust may be generated during excavation and handling activities. Respiratory protection, fugitive dust control procedures, and air monitoring may be required to protect workers and community.	<p>Technologies are demonstrated and commercially available.</p> <p>Land disposal restrictions apply.</p> <p>Would not interfere with future remedial actions at site.</p>	\$267-488 cu yd ^a (1982) (Environmental Law Institute, 1984).
Recycling	<p>Must comply with NAAQ standards for lead and particulate matter.</p> <p>Worker protection during on-site activities must comply with OSHA health and safety requirements.</p> <p>On-site treatment must comply with RCRA and state operating regulations.</p> <p>Off-site disposal must comply with LDRs (40 CFR Part 268).</p>	No long-term human or environmental risks would be associated with site if successful.	The contaminant that is recovered becomes a product. The reduction of toxicity, mobility, and volume of remaining waste may or may not be significant depending on the extent of the recycling operations.	Dust may be generated during removal and handling activities. Respiratory protection, fugitive dust control procedures, and air monitoring may be required to protect workers and community.	Processes available for battery casing fragments have not been shown practicable for ebonite casings.	No information available.

TABLE 22. (continued)

	Compliance with ARARs	Long-term effectiveness and permanence	Reduction of toxicity, mobility, or volume	Short-term effectiveness	Implementability	Cost
	<p>Off-site transportation must comply with the following:</p> <ul style="list-style-type: none"> o RCRA hazardous waste generator and transportation regulations, o Federal and state DOT transportation regulations. <p>The disposal facilities must comply with RCRA and state regulations for disposal.</p>					

^aUpdated to 1990 using cost indexes in Engineering News Record.

Disadvantages:

- o Costs associated with RCRA off-site disposal are high.
- o Fugitive dust control may be expensive.

Problems and Concerns:

- o The location of the RCRA-compliant landfill, to which the contents of waste piles would be transported, has a substantial impact on cost.
- o LDRs may affect the implementability.

5.3.4.2 Recycling of Battery Casings--

This alternative comprises excavation of the waste piles, followed by on-site separation of battery casing fragments. Separation is followed by recycling (possibly off-site) of those components that can be recycled, RCRA off-site disposal of hazardous non-recyclable components, and on-site disposal of nonhazardous components. During recycling the mixed primary source materials are separated into components of lead fines, plastic, and ebonite.

Waste Pile Washing via BOM Process--This technology, developed by the Bureau of Mines, is similar to acid leaching of soil but somewhat less complicated. However, it is unproven and requires testing to determine its feasibility. In this process, battery casings are washed with a leaching agent such as nitric acid to remove lead. Bench-scale treatability studies shown in Table 16, performed on battery casings at the C&R Lead Battery Site, showed good removal efficiencies. Samples of residual battery casing materials, after leaching, had an EP Toxicity lead concentration of less than 5 mg/L (Schmidt, 1989 and NUS, 1990).

Figure 5 shows the U.S. Bureau of Mines process. The waste pile is first screened and washed. The sludge washed from the plastic/ebonite casings is recovered as a by-product. The casings are then subjected to a carbonation step, followed by granulation, and recovery of the metallic lead particles. The casings are then subjected to a nitric acid leach, followed by the addition of sulfuric acid to precipitate the lead in solution as lead sulfate, which is sold as a by-product. The cleaned plastic casing chips can be sold to a plastic manufacturer for recycling.

Bench- and pilot-scale treatability studies must be conducted to determine the feasibility of this technology.

Advantages:

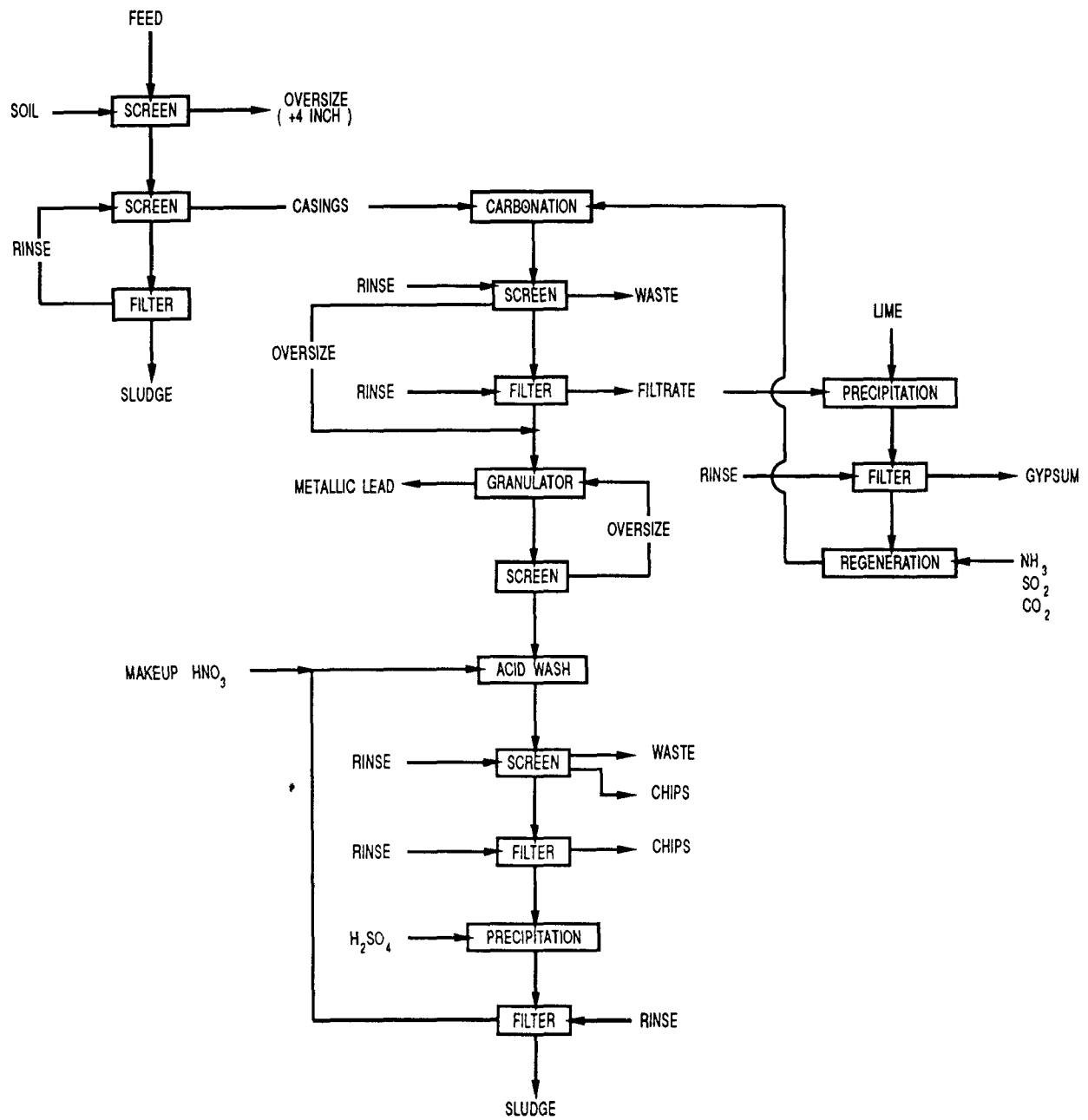
- o Usable by-products (lead and plastic) may be recovered.

Disadvantages:

- o Pilot- and full-scale treatment is unproven.

Problems and Concerns:

- o Laboratory and pilot-scale testing are necessary to determine technical/economic feasibility.



Source: Schmidt, 1989

Figure 5. Bureau of Mines battery casing washing process.

- o Effluents from washing systems require post-treatment and/or RCRA disposal.

Canonie Recycling Process--Canonie Environmental Services Corp. under contract to NL Industries, Inc. has developed a proprietary process for remediating lead battery and smelting wastes at the Gould Site in Portland, Oregon (Canonie Environmental, undated). The process uses a liberation and separation approach to separate the waste materials into recyclable and nonrecyclable products. The process operates principally with water; it does not import toxic chemicals to the site. The recyclable products consist of:

- o Materials with a lead content sufficiently high for recycling, and
- o Cleaned materials such as plastic and ebonite that will pass the EP Toxicity test for lead.
- o The materials that cannot be cleaned to pass the EP Toxicity test for lead and do not contain sufficient lead for recycling are considered "nonrecyclable".

The process is shown schematically in Figure 6. The battery casing is crushed and washed in the first stage. The fines are screened from the washed material, the solids are separated from the water in a settling tank, and the settled pulp is filtered from the solution. These materials are the filter cake that will typically contain more than 40% lead and less than 30% moisture.

Following the first wash, the screen oversize is fed to a gravity separation device. This system separates the plastic and ebonite in the waste from furnace products, rocks, and trash excavated with the waste. The trash products are collected and stabilized for on-site disposal or off-site disposal in a Class I landfill.

The ebonite and plastic material passes to the second wash stage where the residual amounts of lead contamination are removed. The second wash is specifically designed to clean these materials so that they will pass the EP Toxicity test for lead. The cleaned material will typically contain between 100 and 500 ppm total lead.

Performance at the Gould Site--The Gould site contains approximately 117,500 tons of waste. Canonie claims that its process there could produce approximately 80,500 tons of recyclable materials and 37,000 tons of material for stabilization and subsequent on-site disposal. At other sites, the amount of recyclable material may vary according to site history and use (Canonie Environmental, undated).

Advantages:

- o Process operates principally with water; it does not bring toxic chemicals on-site.
- o It reduces the quantity of material of hazardous waste that must be sent for disposal.
- o It can obtain from the waste a product with a higher economic value than the waste.

Disadvantages:

- o Wastes must be properly disposed.
- o Effluent from washing systems requires further treatment before discharge.

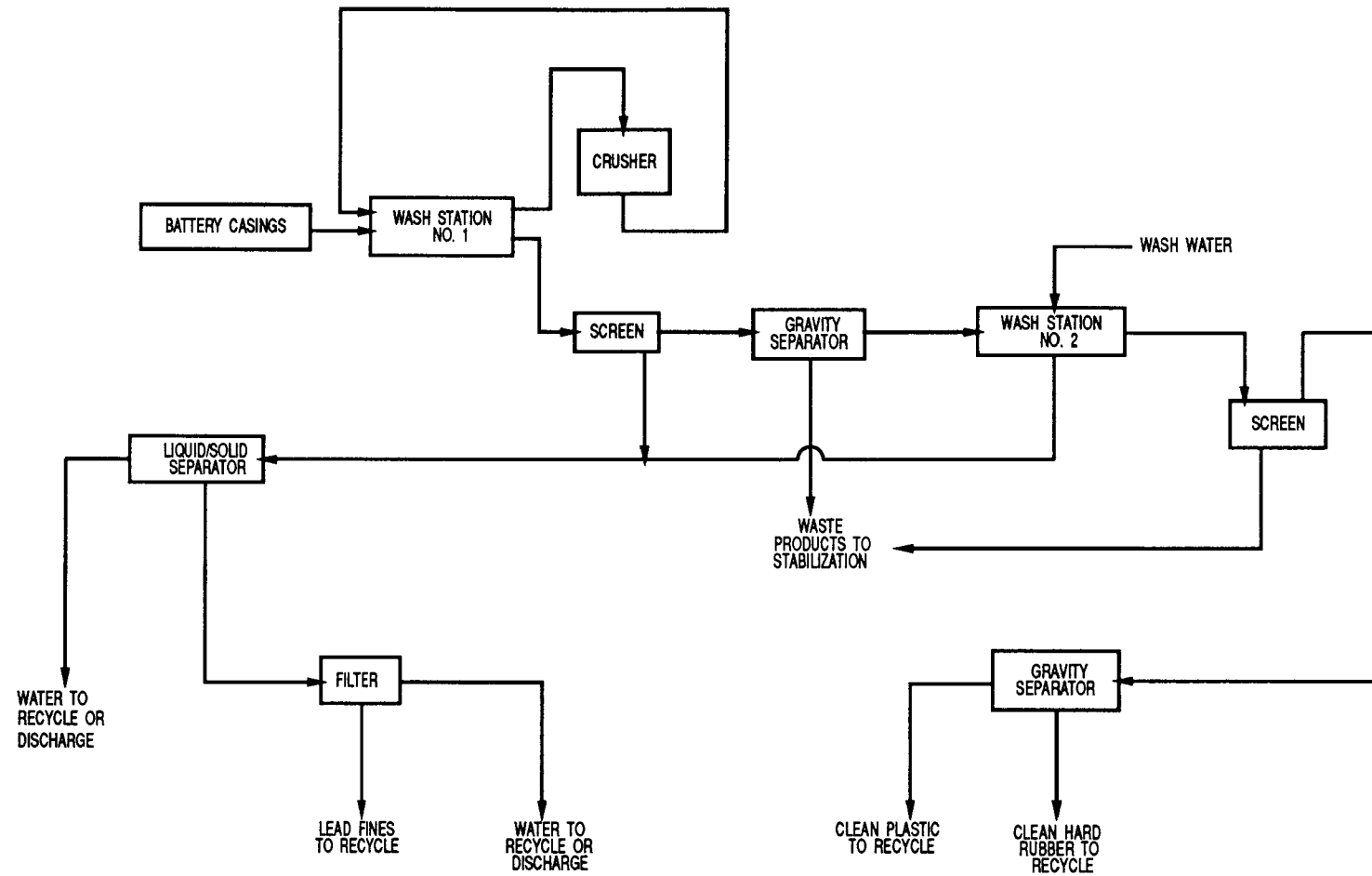


Figure 6. Battery waste treatment process.

Source: Canonie Environmental

Problems and Concerns:

- o The technology is still developmental.
- o The market for clean ebonite should be confirmed.

Commercial Recycling Operations--PEI conducted a study for USEPA to evaluate commercial recycling as a remedial alternative for battery casing contamination at the Gould site in Portland, Oregon. It identified seven companies with recycling capabilities (Arca Engineering, DeLatte Metals, Engitec Impianti, Galena Industries, Interstate Lead Co., M.A. Industries, and Poly-Cycle Industries). Table 23 lists the companies and summarizes pertinent data about their six processes, such as the wash solutions and the final lead content of the recycled ebonite. Arca Engineering and Galena Industries use the Cal West equipment. None of the seven companies, with the possible exception of those using the Cal West equipment, were reported to have successfully separated a waste battery pile and produced an ebonite product that meets the EP Toxicity standard for lead. Cleaning battery wastes from a Superfund site is difficult for the following reasons:

- o The presence of rock and slag that must be removed to avoid damaging the process equipment.
- o The presence of soil, which presents two problems: foaming, and degradation of the lead oxide product. The soil usually remains with similarly-sized lead oxide particles. Foaming can be prevented by adding appropriate chemicals.
- o Lead oxide may be more firmly embedded in the ebonite by lengthy storage in the ground, making these two components very difficult to separate.

More information can be obtained from *Survey of Commercial Battery Recyclers, A Draft Report* (PEI Associates, Inc., 1988).

5.3.4.3 Other Innovative Processes--

The Horsehead Resource Development Co., Inc. Flame Reactor Process--The Horsehead flame reactor process is a patented, hydrocarbon-fueled, flash smelting system that treats residues and wastes containing metals. The reactor processes wastes with a very hot reducing gas >2000°C produced from the combustion of solid or gaseous hydrocarbon fuels in oxygen-enriched air. In a compact, low cost reactor, the feed materials react rapidly, allowing a high waste throughput. The end products are a non-leachable slag (glass-like when cooled) and a recyclable heavy metal-enriched oxide, which may be marketable. The volume reduction achieved by the process depends on the chemical and physical properties of the waste.

Electric arc furnace dust, lead blast furnace slag, iron residues, zinc plant leach residues, purification residues, brass mill dusts, and brass mill fumes have been successfully tested. Metal-bearing wastes have also been treated; zinc (up to 40% removal), lead (up to 10%), cadmium (up to 3%), chromium (up to 3%). Other waste feeds contained copper, cobalt, nickel, and arsenic. A SITE demonstration has been scheduled at the Monaca facility in Pennsylvania. It has not been widely tested for use at Superfund site cleanups.

The Risk Reduction Engineering Laboratory (RREL) Debris Washing System--Developed by RREL staff and IT Environmental Programs, Inc. (formerly PEI Associates, Inc.), this technology will decontaminate debris found at Superfund sites throughout the country. The debris washing system has

TABLE 23. SUMMARY OF COMMERCIAL LEAD BATTERY RECYCLING OPERATIONS OFFERED BY SEVEN COMPANIES

Process conditions	Arca Engineering	Delatte Metals	Engitec Impianti	Galena Industries	Interstate Lead Co.	M.A. Industries	Poly-Cycle Industries
Screening for rocks	Manual	Manual	None	Manual	Manual	Manual	Manual
Wash solutions used	Detergents, proprietary ingredients, lead-loc	Water	Water	Detergent, proprietary ingredients, lead-loc	Acid, detergent	Water, detergent	Water
Separation process	Cal West separator (heavy media)	Wet classification	Hydrodynamic separator	Cal West separator (heavy media) Detergent, proprietary ingredients, lead-loc	Specific-gravity separator	Rising current separator, flotation	Flotation air separators
Final ebonite particle size	1/2" to 1"	Unknown	Unknown	1/2" to 1"	3/8" to 1/2"	Unknown	1"
Final lead concentration in ebonite	100 ppm	Unknown	Unknown	50 ppm	Unknown	5,000 ppm	296.8 ppm
Final EP Toxicity of ebonite	5 ppm	Unknown ^a	Unknown ^b	Unknown ^b	<1 ppm	Unknown ^a	Unknown ^b
Process modification	None	Unknown	Add hydrodynamic separator	None	Add extra conveyor and hopper	Add anti-foaming chemicals	Modify wash systems
Installations	Socorro, NM Hermosa Beach, CA	Pontchatoula, LA Milan, Italy	Toronto, Canada Granite City, IL	Socorro, NM	Leeds, AL	Unknown	Jacksonville, TX

^aCompany claims ebonite fails EP Toxicity for lead.^bCompany claims ebonite passes EP Toxicity for lead.

Source: PEI Associates, Inc., 1988

been demonstrated and will be commercially developed by IT Environmental Programs, Inc. The DWS can clean various types of debris (e.g., metallic, masonry, or other solids) that are contaminated with hazardous chemicals such as pesticides, PCBs, lead, and other metals. This process is being evaluated by EPA in the SITE Program. Bench-scale studies conducted on six pieces of debris including plastic spiked with DDT, lindane, PCB and lead sulfate, then washed using surfactant achieved an overall percentage reduction of lead greater than 98%. This technology has potential application to battery casings and other metallic and masonry debris found at lead battery recycling sites.

5.3.5 Contaminated Medium: Buildings, Structures, and Equipment

Contamination of buildings, structures, and equipment is caused primarily by spillage, storage of the hazardous materials in and around lead battery recycling facilities, and fugitive dust. The common remediation technologies are demolition and decontamination. Twenty-one decontamination methodologies, including both traditional and developing techniques, are described in *Guide for Decontaminating Buildings, Structures, and Equipment at Superfund Sites* (USEPA, 1985a). This reference provides the guidance for site cleanup personnel in decontaminating buildings, structures, and equipment. Demolition and detergent or solvent washing have been proposed in RI/FSs and RODs for lead battery recycling sites. None have yet recommended detergent or solvent washing. More often, buildings are demolished and the rubble is sent off-site to landfills. Table 24 summarizes the EPA evaluation criteria of treatment technologies for buildings, structures, and equipment.

5.3.6 Contaminated Medium: Pits, Ponds, Lagoons, and Surface Water

Pits, ponds, lagoons, and surface water typically contain sulfuric acid, lead, and other metals. Contaminated water may be pumped into the system, neutralized with caustic soda or lime, and treated together with groundwater. However, it may be advantageous to treat them separately -- depending on their composition. Contaminated sediments would be dredged mechanically, dewatered, and treated together with contaminated soil.

In order to minimize surface water and run-off from the site as pathways of contaminant migration, drainage control measures have been recommended in RI/FSs and RODs for lead battery recycling sites. Such measures include grading, revegetation, the construction of storm sewers, and the addition of drainage ditches.

**TABLE 24. SUMMARY OF EPA EVALUATION CRITERIA OF REMEDIAL TECHNOLOGIES
FOR BUILDINGS, STRUCTURES, AND EQUIPMENT**

Remedial technology	Compliance with ARARs	Long-term effectiveness and permanence	Reduction of toxicity, mobility, or volume	Short-term effectiveness	Implementability	Cost
Demolition	<p>Must comply with NAAQ standards for lead and particulate matter.</p> <p>Worker protection during on-site activities must comply with OSHA health and safety requirements.</p> <p>Off-site transportation must comply with the following:</p> <ul style="list-style-type: none"> o RCRA hazardous waste generator and transportation regulations, o Federal and state DOT transportation regulations. <p>The disposal facilities must comply with RCRA and state regulations for disposal.</p>	No long-term human health or environmental risks would be associated with the site.	<p>Does not reduce toxicity or volume of contamination.</p> <p>Mobility is reduced by disposal in a RCRA landfill.</p>	Dust may be generated during excavation and handling activities. Respiratory protection, fugitive dust control procedures, and air monitoring may be required to protect workers and community.	<p>Technologies are demonstrated and commercially available.</p> <p>LDRs apply.</p> <p>Action would interfere with future remedial actions at site.</p>	\$8.98/sq ft ^a or \$242/cu yd. (USEPA, 1985a).
Decontamination	<p>Must comply with NAAQ standards for lead and particulate matter.</p> <p>Workers protection during on-site activities must comply with OSHA health and safety requirements.</p>	No long-term human health or environmental risks would be associated if all the contaminants are removed.	<p>Reduces the overall volume of the contaminated buildings.</p> <p>Reduces the toxicity of the buildings by removing the contaminants.</p>	<p>Dust may be generated during decontamination activities.</p> <p>Respiratory protection may be required to protect workers.</p>	<p>Relatively simple to implement. However, it is site-specific.</p> <p>Collection, treatment, and disposal of decontamination fluids are the most difficult concerns of this technology.</p>	No information available.

^aUpdated to 1990 using cost indexes in Engineering News Record.

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GLOSSARY

Alloy:	A substance that is a mixture of two or more metals, or of a metal and a non-metal.
Blast furnace:	A tower-like furnace for separating metal in which a blast of air is forced into the furnace from below, producing the intense heat needed.
Bullion:	Ingots of metal.
Casting:	The process of forming (molten metal) into a particular shape by pouring it into a mold.
Charging:	The process of loading materials in furnaces for heating or melting.
Dross:	Metal oxides in or on molten metal.
Ebonite:	A hard rubber made by treating crude rubber with a large amount of sulfur and subjecting it to intense heat.
Grid:	Metallic plate in a battery storage cell that conducts the electric current and supports the active material (e.g., lead and lead dioxide).
Hammer mills:	Pivoted hammers mounted on a horizontal shaft, used for shredding, component separation, and washing.
Lead-acid battery:	A storage device for electrical current that consists of plates (lead dioxide and lead on metallic lead grids) that are immersed in a sulfuric acid solution within individual cells, and enclosed in an acid-proof case.
Matte:	An impure mixture of sulfides that is produced in smelting.
Plate:	A smooth, flat, relatively thin piece of metal or other materials.
Polypropylene:	A very light, highly resistant, thermoplastic resin used in packaging.
Primary lead smelter:	A system which separates and refines lead from ore using high-temperature furnace/s.
Refining:	Reducing material to a pure state, free from impurities, drosses, etc.
Reverberatory furnace:	A furnace where metal is heated by a flame deflected downward from the roof.
Rotary furnace:	A furnace which gives heat to the crown and maintains heat under the molten metal so that the metal is heated from below as well as above.

Saw-type breaker:	A machine which cuts the top off batteries, thus allowing the acid to drain and permitting removal of the enclosed lead plates.
Secondary lead smelter:	A system which recycles new and old scrap using high temperature furnaces.
Slag:	The fused refuse separated from a metal in the process of smelting.
Smelting:	Melting metallic material to separate impurities from pure metal.
Speiss:	A mixture of metallic arsenides produced during the smelting process.

APPENDIX A
BACKGROUND INFORMATION ON LEAD-ACID BATTERIES,
BATTERY BREAKING, SECONDARY LEAD SMELTING OPERATIONS,
AND CHEMISTRY OF LEAD AND OTHER HEAVY METALS AT LEAD BATTERY RECYCLING SITES

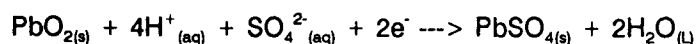
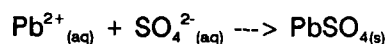
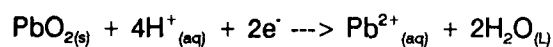
A.1 LEAD-ACID STORAGE BATTERY DESCRIPTION

Most people are familiar with the outward appearance of automotive batteries. However, the RPM for a lead battery recycling site will probably observe various internal and external battery fragments on site. The RPM will review site operating processes and environmental data that require an understanding of battery's physical and chemical composition. Thus, the following descriptive information, drawn predominantly from the Sapp Battery Site Remedial Investigation Report, should be useful to the RPM.

A lead acid storage battery, the essential construction of which is shown in Figure A-1, consists of two electrodes dipped into partly diluted sulfuric acid. The positive electrode (cathode) consists of pure lead dioxide and the negative electrode (anode) is a grid of metallic lead containing various elemental additives including antimony, arsenic, cadmium, copper, and tin.

The following reactions take place on discharge between the two electrodes dipped into the acid electrolyte:

Cathode



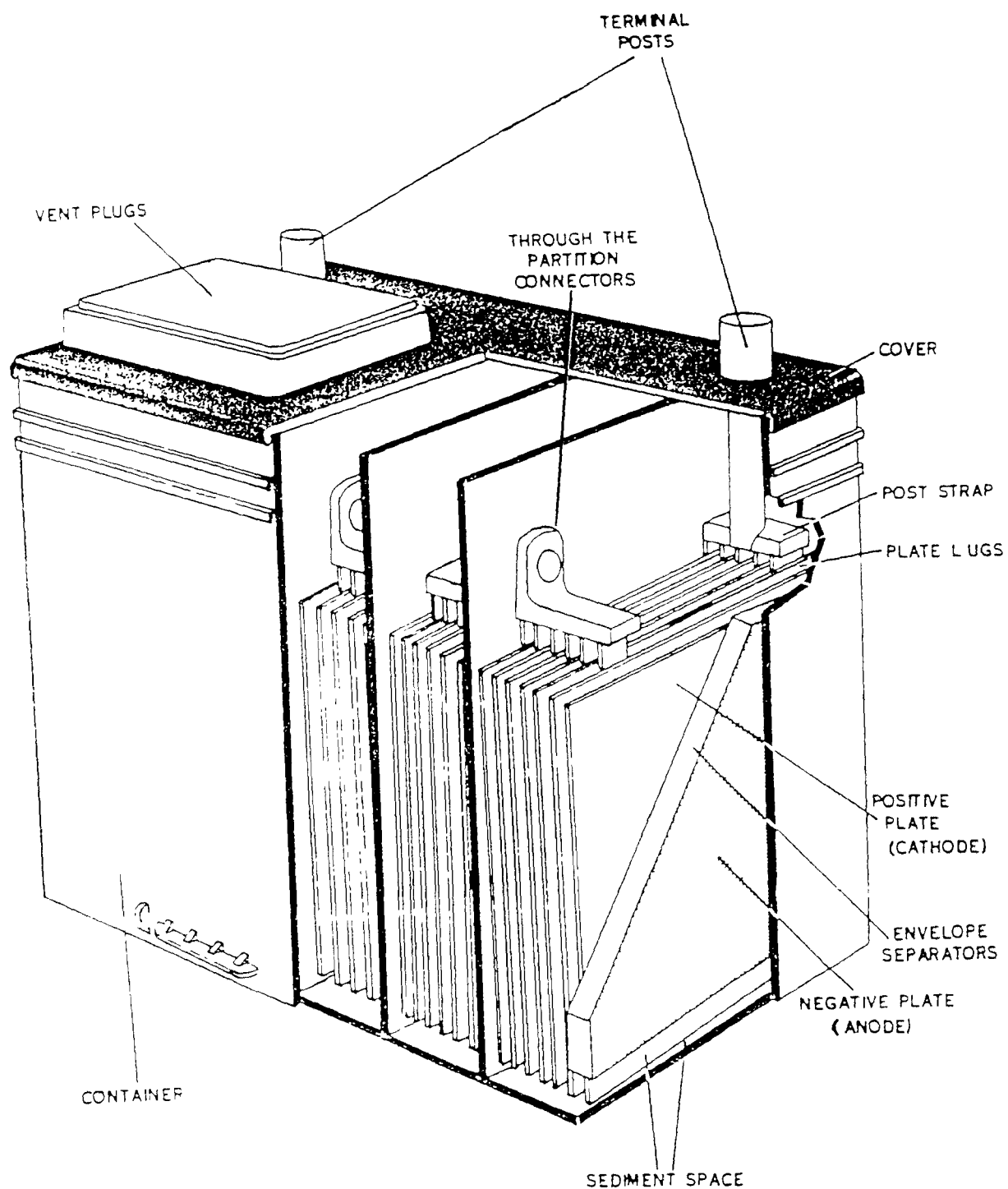
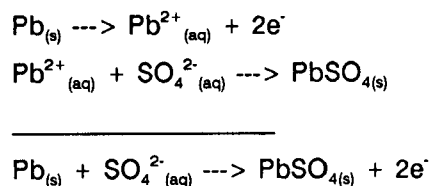


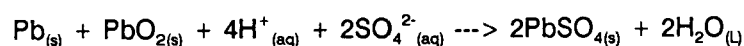
Figure A-1. Lead-acid battery construction.

Source: Watts, 1984

Anode



Overall Reaction



Electrical energy is generated during the reactions above. To recharge the battery, electric energy is applied and the reactions are reversed.

The electrodes are isolated by PVC envelope separators (in the case of maintenance-free batteries) and a fibrous, paper material (in conventional batteries). A standard automotive battery contains 13 or 15 plates per cell, with six cells in series, each delivering 2 volts.

The primary function of the various elemental additives in the lead anode is to increase anode hardness. Table A-1 summarizes these additives and their concentrations.

The electrolyte used in a battery is 15-20% sulfuric acid, which has a specific gravity of 1.250, a pH of 0.8 S.U. and a specific conductivity of $>100,000 \mu\text{mhos/cm}$. Sulfate concentrations range from 130,000 mg/l to 170,000 mg/l. As might be expected, when the sulfuric acid electrolyte is in contact with the electrodes, a certain amount of dissolution takes place. Table A-2 gives the metals concentrations typically found in battery acid.

An average automotive battery weighs 17.2 kg (38 lb), and contains 8.6-9.1 kg (19-20 lb) of lead (equally divided between anode and cathode), 1.4 kg (3 lb) of polypropylene plastic, and approximately 2 liters of sulfuric acid. Although most battery cases are now constructed of polypropylene, they were previously composed primarily of hard rubber material (e.g., ebonite) -- styrene-butadiene cross-linked with sulfur (1%-3%), carbon black or powdered anthracite (30%-50%), and zinc oxide (2%-4%). The ebonite cases were rigid and brittle, with a nominal 1/4-in thickness (Black and Veatch, undated).

TABLE A-1. ELEMENTAL ADDITIVES IN ANODE GRID OF LEAD-ACID STORAGE BATTERY

Element	Concentration range (%)	Purpose
Cadmium	0.1 - 0.14	Grid-hardening agent - no longer used as an additive.
Antimony	2 1/2 - 7 1/2	Grid-hardening agent - high concentrations of antimony tend to poison the electrolytic process.
Arsenic	0.15	Grid-hardening agent - used as substitute for antimony.
Tin	0.10 - 0.5	Grid-hardening agent.
Copper	0.05	Smelting impurity which aids in electrolytic conductivity.
Calcium/lead alloy	--	Prevents hydrogen degassing in maintenance-free batteries.
Selenium/lead alloy	--	Prevents hydrogen degassing in maintenance-free batteries.

Source: Watts, 1984

A.2 BATTERY BREAKING AND SECONDARY LEAD SMELTING DESCRIPTION

The lead recovery aspects of lead-acid battery recycling operations consist of battery breaking, followed by lead smelting and refining, as shown in Figure A-2 (modified from figure in Smith, et al, 1987).

A.2.1 Battery Breaking

Battery breaking is the first step in the lead recycling process. The flow diagram in Figure A-3 depicts the lead-acid battery breaking process. Most breakers are either hammer mills or saw-type breakers. NIOSH divides battery breaking operations into 7 categories (NIOSH, 1982):

TABLE A-2. TYPICAL METALS CONCENTRATIONS IN LEAD-ACID BATTERY ACID

Metal	Concentration (mg/l)
Particulate lead (as lead sulfate >0.45 μ size)	60 - 240
Lead (dissolved)	1 - 6
Arsenic	1 - 6
Antimony	20 - 175
Zinc	1 - 13.5
Tin	1 - 6
Cadmium	5 - 20
Calcium	20 - 150
Iron	112
Selenium	Analysis not available

Note: With the exception of lead, all analyses are for total metals.

Source: Watts, 1984

- (a) Whole battery charging. This technique, developed by the Bergsøe smelter in Denmark, purposely emphasizes as little battery breaking as possible (only about 20% of the battery mass need to be broken). The acid is drained from the battery before charging. "Whole" batteries are mixed with other charge materials on concrete beds using a rubber-tired front-end loader. After the charge is prepared, it is loaded into the furnace by front-end loader. Although it may seem to be a low-level emitting process, emissions and exposures are still a significant problem. Few smelters in the USA use this approach because of the large furnace size required and the resultant poor economics.
- (b) Battery breaking by shear or saw. Many smelters dismantle batteries in a hand operation in which employees (1) separate plastic and rubber batteries, (2) cut the top of the battery off, (3) empty the content of the battery onto a pile. Typically, front-end loaders then move the battery parts to storage and disposal. This operation is labor intensive, creates significant emissions during cutting and handling, and has traditionally been a physically tiring, irritating (acid mist), and high lead exposure job.
- (c) Hammer-mill battery-breaking. In order to speed up the process, remove employee from exposure, and utilize plastic battery cases for fuel or resale, many plants use hammer mills to break batteries. Unfortunately, this approach continues to require hand separation of plastic and rubber cased batteries and manual handling of rubber-cased batteries. Furthermore, the hammer mill is a high-energy machine which creates high levels of lead and acid mist emissions.
- (d) Flotation-type separators. A number of flotation-type battery-breakers are currently employed in today's (1982) smelters. The technique uses shears,

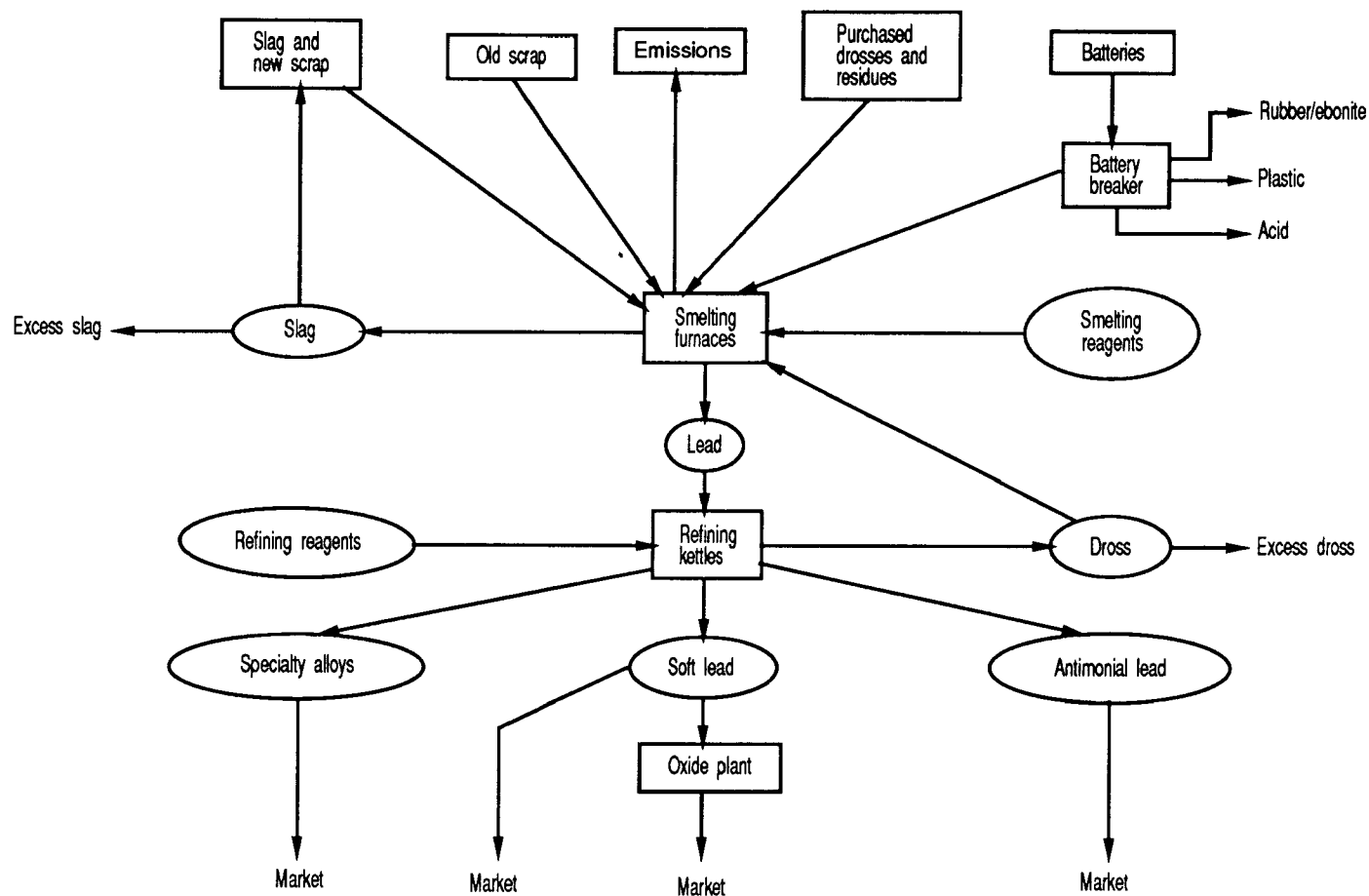


Figure A-2. Generalized secondary lead refining process.
Source: Modified from Smith, et al., 1987

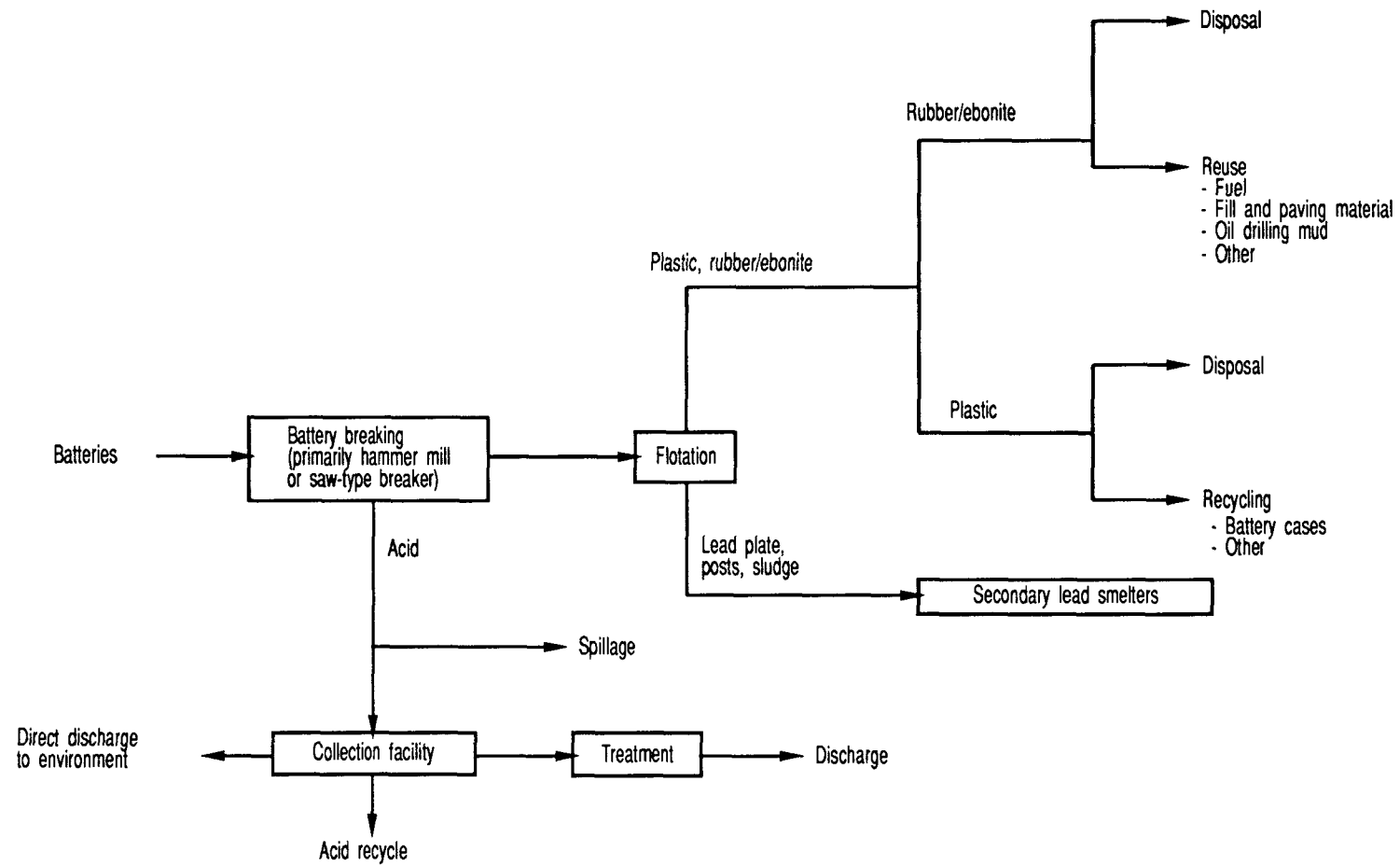


Figure A-3. Flow diagram of lead-acid battery breaking.

saws, and/or hammer mills to reduce battery scrap to small pieces. The separator produces output streams of hard lead (grids and posts), oxide and sulfate sludge, plastic, and rubber. The advantage of this system are (1) positive control of furnace feed enables use of more sophisticated furnaces, e.g., rotary, and (2) separate recycling of plastic case material which, as of December 1981, was selling for 15-17 cents per pound. Unfortunately, as with other approaches, emissions are significant and exposures are high.

- (e) Low-energy shredders. At least five secondary smelters have (or, have had) low energy shredders installed for breaking batteries. This system uses a low rpm, low energy shredding device to slowly shred batteries into chargeable or separable pieces.
- (f) Manual battery breaking. At least one battery breaking operation involved the use of axes to hack the battery casings apart in order to allow acid to drain and permit access to the lead.
- (g) Cracking by dropping. In some operations the batteries are dropped on a hard surface to crack the case and allow the battery acid to drain.

A.2.3 Secondary Lead Smelting (Smith et al, 1987)

The smelting process separates the metal from impurities in either blast, reverberatory, or rotary furnaces. It consists of three basic operations:

- o Initial burnout, which incinerates combustibles.
- o Sweating, which releases lead metal at its low melting point.
- o Slagging, which forms a molten lead layer and a layer of oxidized impurities.

When a charge is heated in a furnace, the pure metal portion melts first, leaving the flux and metallic oxides for conversion to slag.

The blast furnace is used for whole battery scrap. The blast furnace can simultaneously burn out and sweat the charge, thereby conserving fuel and time. However, it is useful only for large operations with a high volume of scraps, and it is incapable of producing lead alloys of different antimony content from the same feed.

A reverberatory furnace can process a finer particle feed, control the antimony content, and carry out batch operations when the supply of scrap material is limited. The furnace produces antimony-rich slag (5 to 9%) and low-antimony lead (less than 1%).

The rotary furnace has the flexibility to produce a single metal product, like the blast furnace. Like the reverberatory furnace, it allows the refiner the option of producing low-antimony lead for further refinement as well as a high- or low-antimonial alloy. However, rotary furnaces tend to produce more exhaust gas and fumes and require more skillful operation than the other two furnaces. They are also more labor intensive.

Refining is the final step in chemically purifying recycled lead. It takes place in oven-topped containers called refining kettles that are constructed of cast iron or steel. The refining process transforms lead bullion to soft pure lead or alloys. After refining and alloying, the metal is pumped into casting machines and water-cooled.

A.3 CHEMISTRY OF LEAD AND OTHER HEAVY METALS AT LEAD BATTERY RECYCLING SITES

Overview

The chemistry of elemental lead and lead compounds is very complex. Lead's complexity is exhibited by the capacity of soils (and associated groundwater) to vary adsorption as a function of pH, cation exchange capacity, organic carbon content, lead speciation, soil/water redox potential, phosphate/carbonate levels, and clay content.

Lead (Pb)

Lead is generally the most widespread and concentrated contaminant present at a lead battery recycling site (i.e., battery breaker or secondary lead smelter). It generally poses the greatest environmental and human health risk.

Lead occurs naturally in crustal material. It is a constituent of more than 200 minerals -- most of them, very rare. The average abundance of lead in the earth's crust is approximately 15 ppm. Lead is commonly associated with ores of copper, zinc, silver, arsenic, and antimony in deposits formed by the replacement of limestone or dolomite. In addition, lead may occur in a variety of igneous, metamorphic, and sedimentary rocks (USGS, 1976).

Weathering of lead-bearing rocks is a very slow process. Analysis of nearly 1,000 soil samples collected from across the U.S. found that the relative abundance of lead in soil ranges from less than 10

ppm to 700 ppm with a mean concentration of 16 ppm. Only 6% of these samples contained greater than 30 ppm of lead (USGS, 1976).

Lead is a heavy metal that exists in three oxidation states: 0, +2(II), and +4(IV). Lead (Pb), lead sulfate (PbSO_4), lead oxide (PbO), and lead dioxide (PbO_2) are the predominant lead species found at a lead battery site. However, the lead species at sites with carbonate soils are generally carbonateous forms, such as lead carbonate (PbCO_3), hydrocerussite ($\text{Pb}_3(\text{CO}_3)_2(\text{OH})_2$), or lead hillite ($\text{Pb}_4\text{SO}_4(\text{CO}_3)_2(\text{OH})_2$). For example, the predominant lead species at the C&R Battery site in Virginia was hydrocerussite.

The metallic lead and lead dioxide electrodes in batteries -- and other lead minerals or salts -- have relatively higher densities than water. Some of the compounds are slightly soluble while others are insoluble in water (Table A-3). Throughout most of the natural environment, the divalent form, Pb^{+2} , is the most stable ionized form.

Lead compounds can also be adsorbed onto hydrous oxides of iron and manganese and be immobilized in double and triple salts. Soils strongly retain lead in their upper few centimeters; they are the major sinks for pollutant lead. Lead can also be biomethylated, forming tetramethyl and tetraethyl lead. These compounds may enter the atmosphere by volatilization.

The capacity of soil to adsorb lead increases with pH, cation exchange capacity, organic carbon content, soil/water Eh (redox potential), and phosphate levels. Lead exhibits a high degree of adsorption on clay-rich soil. Only a small percent of the total lead in soil is leachable; the major portion is usually solid or adsorbed onto soil particles. However, as lead is removed from solution, desorption of lead may occur -- maintaining an elevated lead concentration in solution. Surface runoff, which can transport soil particles containing adsorbed lead, facilitates migration and subsequent desorption from contaminated soils. On the other hand, groundwater (typically low in suspended solids and leachable lead salts) does not normally create a major pathway for lead migration. Lead compounds are soluble only at low pHs. For example, at a pH of 8 or less, the value of dissolved lead could be above the proposed drinking water standard of 15 $\mu\text{g/L}$ (Figure A-4). If battery breaking activities have occurred on-site, and the battery acid was disposed on-site, elevated concentrations of lead and other metals may have migrated to groundwater.

TABLE A-3. SOME PHYSICOCHEMICAL PROPERTIES OF SELECTED LEAD COMPOUNDS

Compound	Formula	Molecular weight (g/mole)	Water solubility	Vapor pressure (mm Hg)
Lead	Pb	207.20	Insoluble	1.0 (980°C)
Lead dioxide	PbO ₂	239.19	Insoluble	NA
Lead carbonate	PbCO ₃	267.20	1.1 mg/l @ 20°C	NA
Lead hydro-cerussite	Pb ₃ (CO ₃) ₂ (OH) ₂	775.60	Insoluble	NA
Lead hydroxide	Pb(OH) ₂	241.20	155 mg/l @ 20°C	NA
Lead sulfide	PbS	239.25	0.9 mg/l @ 18°C	NA
Lead oxide	PbO	223.20	17 mg/l @ 20°C	NA
Lead sulfate	PbSO ₄	303.26	41 mg/l @ 20°C	NA
Tetramethyl lead	(CH ₃) ₄ Pb	267.35	15 mg/l ^a	22.5 @ 20°C
Tetraethyl lead	(C ₂ H ₅) ₄ Pb	323.44	0.8 mg/l @ 20°C	0.15 @ 20°C

a Temperature not available.

NA Not available

Arsenic (As)

Arsenic is used as a grid hardening agent in lead batteries. Its concentration ranges between 1-6 mg/L in battery acid. Four oxidation states (-3, 0, +3, and +5) are possible for arsenic in the natural environment. The +3 and +5 states are most commonly found in aqueous solutions. The +5 state is the most stable and dominant. The environmental behavior of arsenic is largely determined by pH and the oxidation-reduction (i.e., redox) potential of the system. Adsorption of +3 state in soils increases with rising pH over the range of 3 to 9. Arsenic is strongly adsorbed to soil and sediments. Arsenic mobility in an aquatic system will be controlled by sediment movement. In subsurface soils and groundwater, arsenic will be relatively immobile with the As(V) species less mobile than the As(III) species.

Antimony (Sb)

Antimony also a grid hardening agent used in lead batteries. Its concentration ranges between 20-175 mg/L in battery acid. Significant concentrations of antimony are present in the wastewater from the secondary lead plants. The +3 and +5 states are most commonly found in nature. Antimony undergoes deep hydrolysis in dilute solutions. Over a hundred antimony-containing mineral ores exist in nature. The most important mineral is stibnite (Sb₂S₃).

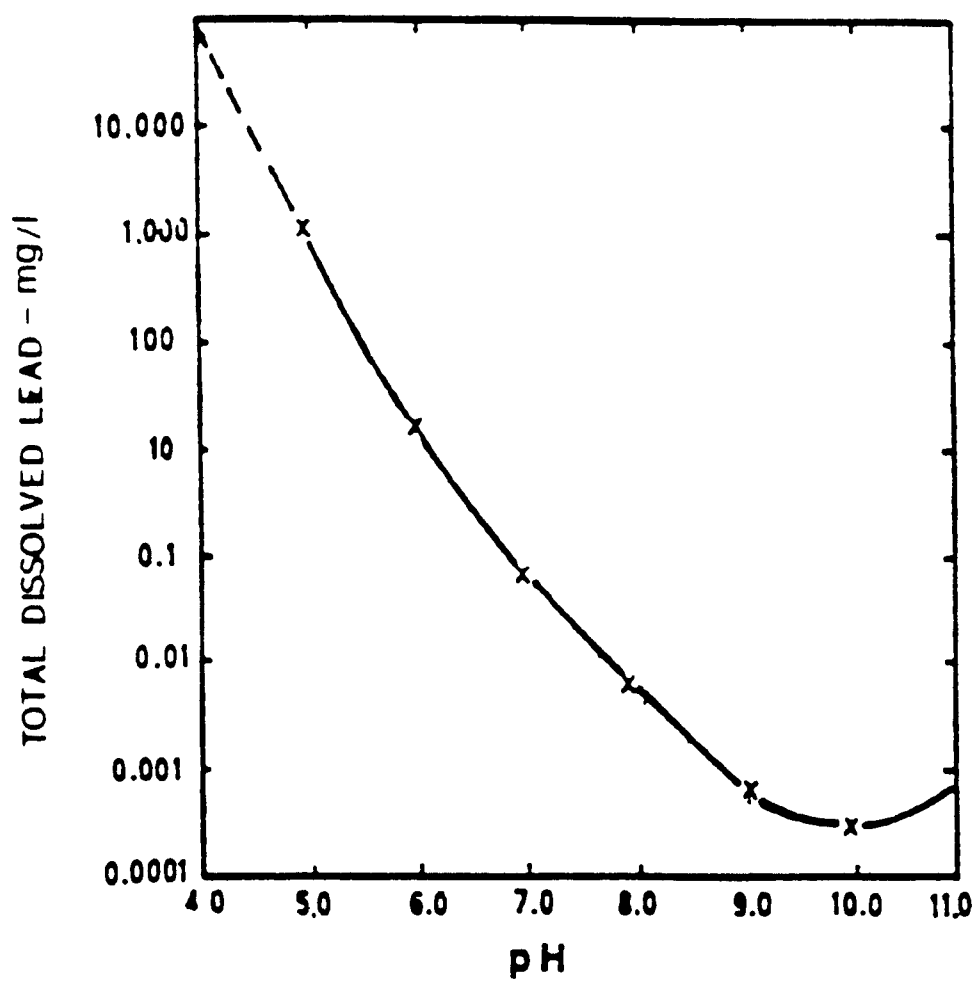


Figure A-4. Equilibrium solubility of lead at 25°C and 1 atm

Source: Watts, 1984

Cadmium (Cd)

Cadmium was used in the past as a grid hardening agent in lead batteries. Its concentration ranges between 5-20 mg/L. In aqueous solutions, cadmium exists only in the +2 state. Cadmium is adsorbed by soils and sediments containing aluminum, iron, and manganese oxides. Cadmium mobility in aquatic systems will be controlled by sediment movement. In subsurface soil and groundwater, cadmium will be relatively immobile.

APPENDIX B
BACKGROUND INFORMATION ON
SUPERFUND LEAD BATTERY RECYCLING SITES

B.1 IDENTIFICATION AND CLASSIFICATION OF LEAD BATTERY SITES

During the course of this project, 44 CERCLA lead battery Superfund sites were identified. Table B-1 provides a brief summary of the sites, including a contact point, where available. These lead battery sites consisted of two main groups: lead battery recycling sites and non-recycling sites.

1. Lead battery recycling sites -- Twenty-nine (29) lead battery recycling sites were identified. A lead battery recycling site is defined in this report as a location where battery breaking, secondary lead smelting, or lead refining operations have been conducted. The lead battery recycling sites can be further classified into two sub-groups:
 - (a) Battery breaker sites (20 identified), where operations consisted principally of battery breaking, with the recovered lead being taken off-site for further processing; and,
 - (b) Integrated battery breaking/smelting/refining sites (9 identified).

Of these 29 lead battery recycling sites, 22 are on the Eighth Update to the National Priority List (NPL) and have been or will be subjected to the Remedial Investigation/Feasibility Study process. Some of these 22 sites on the NPL have also been the subject of removal actions. The other 7 lead battery recycling sites are those where only removal actions are underway or completed.

Of the 22 lead battery recycling sites on the NPL, 10 have completed RODs; 8 of those RODs were reviewed in preparation of this report. Remedial Investigation and Feasibility Study reports were obtained for 8 of these sites. Additional documents on several of

TABLE B-1. SUMMARY OF CERCLA LEAD BATTERY SITES AND REMEDIAL ALTERNATIVES PROPOSED (9/90)

Site name/location/state/ NPL ID#/EPA ID#/point of contact (POC)	Region	Site description	Threat/problem	Selected remedy,* present worth capital and O&M costs, ROD date
1. New London Sub Marine Base, New London, CT NPL ID#: 01CT021 EPA ID#: Paul Marchessault FTS-883-1793	I	Submarine battery servicing facility. Volatile organic compounds pesticides, PCBs, and spent battery acids buried below the water table in Area A landfill.	Sediment and surface water contaminated with metals and pesticides.	Remedy not selected. Remedial investigation in progress. Monitoring wells installed, sampling to begin 11/90.
2. NL Industries, Pedricktown, NJ NPL ID#: 02NJ060 EPA ID#: NJD061843249 Mick Gilbert FTS-264-6418 Eugene Dominach FTS-340-6666	II	Integrated battery breaking/ lead smelting/refining facility/on-site landfill (11 acres).	Soil, groundwater, surface water contaminated with heavy metals.	RI/FS in progress. Landfill capped, leachate collection and treatment underway.
3. Brown's Battery Breaking Site, Shoemakersville, PA NPL ID#: 03PA060 EPA ID#: PAD980831812 Chris Corbett FTS-597-6906	III	Battery breaking facility (14 acres).	Soil, groundwater, and sediments contaminated with metals including lead.	Permanent relocation of all on-site residences and the on-site business. \$342,900 (present worth). ROD for other operable units pending. 9/28/90.
4. C&R Battery Co., Inc., Chesterfield County, VA NPL ID#: 03VA017 EPA ID#: VAD049957913 Paul Leonard FTS-597-1286	III	Battery breaking facility (11 acres).	Soil contaminated with inorganics including lead, antimony, and arsenic.	Stabilization of contaminated soil and sediment; off-site disposal of the stabilized material in a sanitary/ industrial waste landfill; residual contaminated soil covered with a soil cap. \$15,572,000 (present worth). 3/30/90.
5. Dorney Road Landfill, Mertztown, PA NPL ID#: EPA ID#: PAD980508832 POC: Not determined	III	Landfill with some lead battery waste.	Soil and surface water contaminated with VOCs, organics, and inorganics.	Off-site disposal of ponded water; regrading and installation of multi- layer cap; runoff/runoff controls; runoff and groundwater monitoring; access and deed restrictions. \$14,000,000 (present worth) \$42,000 (annual O&M). 9/29/88.

(continued)

* Remediation selected in RODs have not been implemented (9/90).

TABLE B-1. (continued)

Site name/location/state/ NPL ID#/EPA ID#/point of contact (POC)	Region	Site description	Threat/problem	Selected remedy,* present worth capital and O&M costs, ROD date
6. Hebelka Auto Salvage Yard, Weisenburg Township, PA NPL ID#: EPA ID#: PAD980829329 Fran Burns FTS-597-4750	III	Automobile junk yard with intermittent periods of activity involving salvage operations (20 acres).	Soil and debris (battery casings) contaminated with metals including lead.	Excavation and on-site fixation of soil followed by off-site disposal; excavation and recycling of battery casings; soil backfilling and vegetation. \$6,073,436-6,884,652 (present worth), \$0 (O&M). 3/31/89.
7. Jacks Creek/Sitkin Smelting and Refining, Maitland, PA NPL ID#: 03PA125 EPA ID#: PAD980829493 Garth Conner FTS-597-0439	III	Smelting/refining facility and mining operation.	Soil contaminated with PCBs, surface water contaminated with lead and PCBs.	Pre-RI activities in progress.
8. Lancaster Battery, Lancaster, PA NPL ID#: EPA ID#: PAD003004496 POC: Not determined	III	Former recycler of lead batteries from automobiles and trucks.	Soil, groundwater, and surface water contaminated with metals including lead, arsenic, cadmium, and copper.	Removal action -- about 1,400 tons of lead- contaminated soil excavated and disposed at off-site disposal facilities.
9. Reeser's Landfill, PA NPL ID#: EPA ID#: PAD980829261 Vic Janosik FTS-597-8996	III	Unlined municipal dump that contained some battery cases.	None.	No action. Groundwater review due within five years. 3/30/89.
10. Tonolli Corp., Nesquehoning, PA NPL ID#: 03PA123 EPA ID#: PAD073613663 Donna McCartney FTS-597-1101	III	Integrated battery breaker/ smelter/refiner (30 acres).	Soil and waste piles contaminated with metals including lead, arsenic, cadmium, and copper.	RI/FS in progress. Removal actions included draining and treating contaminated lagoon water.

(continued)

* Remediation selected in RODs have not been implemented (9/90).

TABLE B-1. (continued)

Site name/location/state/ NPL ID#/EPA ID#/point of contact (POC)	Region	Site description	Threat/problem	Selected remedy,* present worth capital and O&M costs, ROD date
11. Voortman Farm, Upper Saucon Township, PA NPL ID#: 03PA123 EPA ID#: PAD980692719 Nick Dinardo FTS-597-3541	III	Batteries dumped in sinkhole, not a battery recycler (43 acres).	Groundwater monitored for contaminated from metals including lead and cadmium.	No action. Continued groundwater monitoring. \$26,010 (present worth) \$6,860 (annual O&M). 6/30/88.
12. Bypass 601 Groundwater Contamination, Concord, NC NPL ID#: EPA ID#: Al Cherry FTS-257-7791	IV	Abandoned battery salvage and recycling facility (13 acres).	Soil contaminated with lead, chromium, nickel, and sulfate.	RI/FS in progress. Alternatives under consideration: no action, capping, in-situ solidification on-site treatment and disposal, off-site treatment and disposal.
13. Cedartown Battery, Inc. Cedartown, GA NPL ID#: EPA ID#: GAD984273821 Larry Brannen FTS-257-3931	IV	Battery breaking facility.	Not determined.	Removal action -- contract for solidifi- cation of 22,000 y ³ of lead-contaminated soil awarded, implementation planned for late 1990 and early 1991.
14. Cedartown Industries, Inc., Cedartown, GA NPL ID#: 04GA017 EPA ID#: GAD095840674 Randy Dominy FTS-257-2643	IV	Battery breaking and secondary lead smelting facility (7 acres).	Soil and sediments contaminated with lead.	Not determined.
15. Gulf Battery Exchange, Ocean Springs, MS NPL ID#: EPA ID#: MSD064626195 POC: Not determined	IV	Battery crushing facility.	Soil, surface water, and groundwater contaminated with lead.	Removal action (1983-84) - off-site disposal of contaminated soils and acid. On-site con- solidation and capping of soils.
16. Interstate Lead Co., (ILCO) Leeds, AL NPL ID#: 04AL014 EPA ID#: ALD041906173 Anna Torgrimson FTS-257-2643	IV	Battery breaking/secondary lead smelting facility. On-site and off-site disposal of lead-bearing wastes.	Groundwater and sediments contaminated with lead.	Installation of clay cap over some areas completed under partial consent decree. Feasibility study yet to be completed.

(continued)

* Remediation selected in RODs have not been implemented (9/90).

TABLE B-1. (continued)

Site name/location/state/ NPL ID#/EPA ID#/point of contact (POC)	Region	Site description	Threat/problem	Selected remedy,* present worth capital and O&M costs, ROD date
17. Kassouf-Kimerling Battery, Tampa, FL NPL ID#: EPA ID#: Dave Abbott FTS-257-2643	IV	Landfill where empty lead-acid battery casings were deposited (1 acre).	Soil, debris, and ground- water contaminated with metals including arsenic, cadmium, and lead.	ROD 1, Landfill, 3/31/89 -- Excavation of landfill wastes and underlying soil following by solidifi- cation/chemical fixation and disposal in on-site landfill. \$2,500,000-3,500,000. 3/30/90. ROD 2, Marsh, 3/30/90 - Excavation and treatment by solidification of contaminated marsh sediments; sediment beyond 20 ft from landfill and 150 ft in drainage canal to be left in place.
18. Palmetto Recycling, Inc. Columbia, SC NPL ID#: 04SC023 EPA ID#: SCD003362217 Al Cherry FTS-257-7791	IV	Battery breaking facility (2 acres).	Soil and sediments contaminated with metals including lead, cadmium, and chromium.	Pre-R1.
19. Sapp Battery Salvage, Cottondale, FL NPL ID#: 04FL018 EPA ID#: FLD980602882 Martha Berry FTS-257-2643	IV	Battery breaking facility. Extensive environmental damage to cypress swamp (45 acres).	Groundwater, surface water, and sediments contaminated with metals.	Excavation, solidification/fixation, and on-site disposal of solidified soil and sediments; groundwater pump and treatment; surface water treatment and discharge; and assessment of potential institutional controls. \$14,318,544 (capital), \$25,631 (annual O&M) 9/26/86.
20. Schuylkill Metals Corp., Plant City, FL NPL ID#: 04FL019 EPA ID#: FLD062794003 Barbara Dick FTS-257-2643	IV	Battery breaking facility. Marsh contaminated due to operations. (17 acres).	Soil and sediment con- taminated with lead, groundwater, and surface water contaminated with lead, chromium, and nickel.	Excavation of process area soil; separation of soil and debris by screening; treatment of the soils by chemical fixation; crushing and washing of debris for recycling; treat- ment of surface water and groundwater by ion medium filtration. Marsh remediation will involve mechani- cal controls, i.e., fencing and monitoring for west marsh and flood control gates to provide continued surface water inundation resulting in anaerobic sediments and monitoring for the east marsh.

(continued)

* Remediation selected in RODs have not been implemented (9/90).

TABLE B-1. (continued)

Site name/location/state/ NPL ID#/EPA ID#/point of contact (POC)	Region	Site description	Threat/problem	Selected remedy,* present worth capital and O&M costs, ROD date
21. Scott's Creek, New Bern, NC NPL ID#: EPA ID#: MCD980848840 POC: Not determined	IV	Old batteries located on-site.	Soil, groundwater, and surface water contaminated with lead.	Removal action - about 490 y ³ of lead-contaminated fill and battery casings excavated and deposited off-site.
22. Arcanum Iron and Metal Site, Darke County, OH NPL ID#: 05OH003 EPA ID#: OH0017506171 Anita Boseman FTS-886-6941	V	Battery breaking facility (4.5 acres).	Groundwater, surface water, soil, and sediments contaminated with inorganics, including lead, antimony, and arsenic.	Excavation and off-site disposal of soil with >500 mg/kg lead; excavation and on- site disposal of soil with lead between background and 500 mg/kg; removal of battery casings; conduct treatability studies and on-site landfilling; and deed restrictions on land and aquifer usage. \$9,929,000 (capital), \$37,000 (annual O&M). 9/26/86.
23. H. Brown Co., Inc. Grand Rapids, MI NPL ID#: 05MI108 EPA ID#: MID017075136 Timothy Prendiville FTS-886-5152	V	Battery breaking facility, portions of facility also used as a dump (4 acres).	Lead contamination in air, surface water, sediments, and groundwater.	RI in progress.
24. NL Industries/Taracorp Lead Smelter, Granite City, IL NPL ID#: 05IL035 EPA ID#: ILD096731468 Brad Bradley FTS-886-4742	V	Integrated battery breaking and secondary lead smelting facility (25 acres).	Soil contaminated with lead.	Excavation of soils from residential and commercial areas, consolidation in on-site pile, followed by multi-media capping. 9/86.
25. NL Industries/Taracorp/Golden Auto Parts, St. Louis Park, MN NPL ID#: EPA ID#: POC: Not determined	V	Integrated battery breaking and secondary lead smelting facility.	None.	No action. Continued groundwater monitoring. 9/29/88.

(continued)

* Remediation selected in RODs have not been implemented (9/90).

TABLE B-1. (continued)

Site name/location/state/ NPL ID#/EPA ID#/point of contact (POC)	Region	Site description	Threat/problem	Selected remedy,* present worth capital and O&M costs, ROD date
26. Prestolite Battery Division, Vincennes, IN NPL ID#: EPA ID#: Bob Lance FTS-886-4745	V	Former battery manufacturing site (3.6 acres).	Soil contaminated with lead.	Not determined.
27. Rosen Metals/Ken Lee Prop., Woodville, WI (also known as Lee's Farm) NPL ID#: EPA ID#: WID980615553 Steven Faryan FTS-353-9351	V	Abandoned stone quarry used to dispose of battery casings (1.5 acres).	Soils and sediments contaminated with lead.	Chemical fixation of the lead-contaminated waste using the Regional ERCS contractor's proprietary treatment process, and capping treated material on-site. Removal action in progress. 11/90.
28. Rosen Metals/Phoenix Metals, Baldwin, WI NPL ID#: EPA ID#: WID023145592 Steven Faryan FTS-353-9351	V	Burned battery tops to recover lead.	Soil contaminated with lead.	Not determined.
29. Scrap Processing Co., Inc., Medford, WI NPL ID#: 05WI034 EPA ID#: WID046536785 Bill Messenger FTS-353-1057	V	Auto salvage operation that included battery breaking facility (2 acres).	Acidic, lead-bearing soil in pond, potential threat to groundwater.	Not determined.
30. Union Scrap Iron and Metal Co., Minneapolis, MN NPL ID#: 05MN020 EPA ID#: MND022949192 Jim Vanderkloot FTS-353-9309	V	Automobile battery breaking operations (1 acre).	None.	No action. 3/30/90.

(continued)

* Remediation selected in RODs have not been implemented (9/90).

TABLE B-1. (continued)

Site name/location/state/ NPL ID#/EPA ID#/point of contact (POC)	Region	Site description	Threat/problem	Selected remedy,* present worth capital and O&M costs, ROD date
31. United Scrap Lead Co., Inc., Troy, OH NPL ID#: 05OH044 EPA ID#: OH0018392928 Anita Boseman FTS-886-6941	V	Battery breaking facility (25 acres).	Soil and sediments contaminated with arsenic and lead.	Excavation and treatment of battery casings and contaminated soil by washing, with lead recovery and off-site disposal or recycling of casings, and replacement of residual soils on-site; excavation and dewatering of sediments on-site and disposal with soil; construction of a soil cover, and revegetation; decontamination of contaminated buildings and debris with off- site disposal; installation of a new residential well; deed restrictions; drainage control; and Groundwater and surface water monitoring. \$26,924,000 (present worth), \$55,375 (annual O&M). 9/30/88.
32. Cal West Metals, Lemitar, NM NPL ID#: 06NM0111 EPA ID#: NM0097960272 Monica Chapa 214-655-6730 Carlos Sanchaz FTS-255-6710	VI	Processed automobile batteries to recover lead.	Soil, groundwater, surface water, and sediments contaminated with lead.	RI in progress.
33. Michael Co., (Bettendorf) Bettendorf, IA NPL ID#: IAD021693338 EPA ID#: IAD021693338 William Bunn FTS-276-7792 Roy Crossland FTS-757-3881	VII	Former battery manufacturing and recycling facility. There are three other similar sites contaminated by the same company (each <1 acre).	Soil and SW contami- nated with lead.	Removal action -- excavation of soil >1,000 ppm and off-site disposal. Building interiors decon- taminated via sweeping/vacuuming/steam-cleaning.
34. Murrieta Christian School, Murrieta, CA NPL ID#: CAD982405409 EPA ID#: CAD982405409 Brad Shipley FTS-484-1026	IX	Defunct battery manufacturing site on which a small private school was built.	Soil, surface water, groundwater contaminatd with lead.	Removal action -- consolidate contaminated soils, add quick lime, apply a graded, 4-inch aggregate base covered by a 3-inch asphalt cap.

(continued)

* Remediation selected in RODs have not been implemented (9/90).

TABLE B-1. (continued)

Site name/location/state/ NPL ID#/EPA ID#/point of contact (POC)	Region	Site description	Threat/problem	Selected remedy,* present worth capital and O&M costs, ROD date
35. Norco Site, Norco, CA NPL ID#: EPA ID#: CAD982040057 Richard Martyn FTS-744-1914	IX	A former battery breaking facility (16 acres).	Not determined.	Removal action -- cement-based solidification used to treat approximately 8,000 tons of soil. TCLP after 28 days <1 mg/L; AWS 16.1 greater than leach index of 12; unconfined compressive strength >500 psi.
36. Alaska Battery Enterprises, Fairbanks, AK NPL ID#: 10AK002 EPA ID#: AKD004904215 Jeff Webb FTS-399-6707	X	Battery sales, recycling and battery parts casting opera- tions were conducted on-site (<1 acre).	Soil and groundwater contaminated with lead.	Removal action -- excavation of lead-contaminated soil above 1,000 mg/kg and disposal in a RCRA- landfill. Site listed on NPL.
37. Alaska Husky Battery, Inc., Anchorage, AK NPL ID#: EPA ID#: AKD009246497 POC: Not determined	X	Battery breaking facility.	Groundwater contaminated with lead and PCBs.	Removal action -- approximately 1,580 y ³ of PCB and lead-contaminated soil were excavated and sent for disposal off-site.
38. Arctic Surplus, Fairbanks, AK NPL ID#: 10AK008 EPA ID#: POC: Not determined	X	Salvage operations including battery breaking (22 acres).	Soil and groundwater contaminated with lead, zinc, PCBs, chlordane, phenanthrene, and pyrene.	EPA-initiated removal action in Sept. 1989: fencing the site, removing 22,000 lbs of asbestos, stabilizing approximately 75 gal of chlordane, collecting groundwater samples, and better defining waste streams on-site. Site listed on NPL.

(continued)

* Remediation selected in RODs have not been implemented (9/90).

TABLE B-1. (continued)

Site name/location/state/ NPL ID#/EPA ID#/point of contact (POC)	Region	Site description	Threat/problem	Selected remedy,* present worth capital and O&M costs, ROD date
39. Gould, Inc., Portland, OR NPL ID#: 100R002 EPA ID#: ORD095003687 Chip Humphrey FTS-423-2678	X	Battery breaking and lead smelting facility (60 acres).	Soil and sediments contaminated with metals including lead.	Excavation and separation of battery casing fragments and matte; recycling of components that can be recycled; off-site RCRA landfill disposal for nonrecyclable components; on-site disposal of nonhazardous, nonrecyclable components; excavation, fixation/stabilization on-site disposal of contaminated soil, sediments, and matte; followed by soil capping, revegetation, and grading; and groundwater, surface water, and air monitoring. \$3,491,603 (capital), \$17,073,581 (present worth O&M). 3/31/88.
40. Hanford 1100-Area, Benton County, WA NPL ID#: 10WA054 EPA ID#: WA4890090075 Dave Einan FTS-444-3883	X	Waste battery acid disposal area (<1 acre).	None.	Pre-RI in progress. ROD due in 1993.
41. Harbor Island/RSR Battery Site, Seattle, WA NPL ID#: 10WA008 EPA ID#: WAD980722839 Keith Rose FTS-399-7721	X	A 350-acre industrial area in Seattle, WA.	Air contaminated with lead.	RI in progress. ROD due in 1992.
42. Spokane Junk Yard, Spokane, WA NPL ID#: EPA ID#: WAD981767296 POC: Not determined	X	Metal salvage and scrapping company that dealt with batteries and transformers.	Soil, surface water, and groundwater contaminated with lead, cadmium, and PCBs.	Removal action partially complete. Excavated lead hot spots and capping of remaining lead- contaminated soils planned.
43. Standard Steel Metal Salvage Yard, Anchorage, AK NPL ID#: EPA ID#: AKD980978787 Johnson/Longston	X	Metal salvage yard.	Soil and surface water contaminated with lead, PCBs, furans, cyanides, and asbestos.	Removal action -- off-site disposal or recycling of contaminated soils stabilized with shotcrete.

(continued)

* Remediation selected in RODs have not been implemented (9/90).

TABLE B-1. (continued)

Site name/location/state/ NPL ID#/EPA ID#/point of contact (POC)	Region	Site description	Threat/problem	Selected remedy,* present worth capital and O&M costs, ROD date
44. Western Processing, Kent, WA NPL ID#: EPA ID#: John Barich FTS-399-8562	X	Recycling site. Battery case chips and battery acid were included in wastes on-site.	Groundwater, surface water, soil, and creek sediments contaminated with VOCs, organics, including PCBs and PAHs, and metals.	Soil sampling and analysis of on-site and off-site areas; excavation and off-site disposal of selected soils and non-soil materials; excavation or cleaning and plugging all utility and process lines in Area 1; Grounwater extraction and treatment; stormwater control; excavation and on-site disposal of selected soils; excavation of utility lines; cleaning utility man- holes and vaults; capping; performing bench-scale testing of soil solidification technique; excavation of Mill Creek sediments; and performing supplemental remedial planning studies if groundwater contamina- tion migrates. \$5,000,000 (capital). 8/5/84 and 9/25/85.

* Remediation selected in RODs have not been implemented (9/90).

these sites (e.g., On-Scene Coordinator Reports, RI/FS Work Plans, and technical papers) were also studied.

2. **Lead battery, non-recycling sites** -- Fifteen of the 44 lead battery Superfund sites had substantial battery-related contamination. At these sites, non-recycling operations included battery acid disposal; auto salvage operations where batteries accumulated; battery disposal (in many cases mixed with other non-battery wastes); and battery manufacturing. Information on these sites was considered valuable for this report if (a) portions of the contamination at the site were distinctly battery-related (that is, not mixed together with a lot of non-battery wastes), and (b) a treatment was underway or completed on the battery-related wastes.

B.2 SUMMARY DESCRIPTION OF CERCLA LEAD BATTERY RECYCLING SITES

1. **Physical Description** -- As can be seen in Appendix A from the descriptions of the battery breaking, smelting, and refining processes, numerous types of operations can occur at these sites. Similar operations may be executed with a range of procedures. Nonetheless, some useful generalizations about these sites are possible.

Battery breaking operations - These enterprises are often small businesses with limited environmental control programs. Battery breaking operations may have been conducted at various places on the site. Disposal of the residuals from the battery breaking operations tends to be haphazard. For instance, spent battery acid may or may not have been treated prior to discharge to a swamp, ditch, pit, or lagoon. Battery casing fragments, battery sludge, and metallic lead chips (separate or mixed) may be placed in piles, buried, mixed with asphalt for use on site roads, or sent off-site for re-use. In a few cases, battery tops were burned in order to remove the casing material and permit recovery of the metallic lead. Battery breaking operations are not necessarily small; 50,000 batteries per week were reportedly processed at one site (Sapp Battery). Also, materials other than batteries were processed at some of these sites, adding non-battery-related contamination.

Organized, integrated, industrial operations - These operations involved processes not only for battery breaking and component segregation, but also for acid handling and

treatment, smelting, refining, air and water pollution control, and in some instances, battery case recycling and battery manufacturing. These facilities are generally owned by large companies with several plants. These companies may have considerable experience with remedial investigations and feasibility studies concerning lead battery sites, either as an owner or PRP. The contamination at these integrated facilities is present in spent acid, metallic lead, lead compounds, and lead-contaminated battery casings. Acid treatment, mechanized battery breaking, component segregation, sizing, and washing are more common at these sites than at battery breaker sites. The integrated battery breaking/smelting/refining sites also generated lead smelting and refining wastes (e.g., lead slag, dross, matte, speiss, dusts, stack emissions, wastewater, and residuals from air and water pollution control). The smelters typically use a landfill or slag pile close to the operation. Wastes from some smelters have been sent off-site (for such uses as alley surfacing, fill material, recycling) or for disposal. Also, some of the reagents (e.g., arsenic, cadmium, and antimony) used in the smelting, refining, and alloying processes -- although used in much small quantities than lead -- are hazardous. They require attention regarding worker safety, site characterization, and if necessary, remedial action. The number and type of buildings, structures, and equipment that require investigation, demolition, or disposal at an integrated battery breaker/smelter/refiner operation is typically greater than for a simple battery breaker site. Plastics reprocessing and battery manufacturing residuals may also be present at integrated battery breaker/smelting/refining sites. There are only a few former plastics reprocessing and battery manufacturing sites that are currently on the NPL. These sites have not had RIs or FSs completed to date, so plastics recycling and battery manufacturing operations are not addressed in this document.

2. Types of Contamination at Defunct Lead Battery Recycling Sites -- The information obtained on lead battery recycling sites shows that RPMs are typically confronted with metallic lead and lead compounds as the principal contaminants of concern. The metallic lead occurs in a variety of alloys and physical forms, (e.g., plates, chips, powders, dusts, bound to battery casing scraps, or incorporated in slag). The lead compounds from scrap batteries include lead sulfate and lead oxides. Other lead compounds (e.g., PbCO_3 , Pb(OH)_2) may be formed in treatment processes that neutralize battery acid. Still other lead compounds may be formed via reactions with the soil.

Other metals (e.g., cadmium, copper, arsenic, antimony, and selenium) are often present at lead battery recycling sites, but usually in much lower concentrations than lead -- often below hazardous concentrations. Also, sulfuric acid from batteries may remain in liquid form in pits, ponds, lagoons, storage tanks, or treatment vessels. The acid may also have contaminated the soil, elevated sulfate levels, and depressed pH. Of course, non-battery recycling operations at these sites, have introduced other contaminants.

Asbestos insulation may also be present on piping and equipment at smelting and refining sites.

3. Contamination Sources at Defunct Lead Battery Recycling Sites --There are five sources of environmental and health risks from defunct lead battery recycling sites:

- o Soil -- Lead-contaminant concentrations are common to lead battery recycling sites. TCLP values exceeding 5 mg/L are typically found in soil samples from these sites, indicating that the soil is a RCRA hazardous waste. Lead in soil is rather immobile. At several sites the lead contamination in the soil does not exceed a depth of a few centimeters. There are, however, exceptions to lead's limited mobility in soil. These exceptions appear to be caused by: (1) excavation and burial of lead-contaminated wastes (e.g., scrap battery parts), or (2) a combination of very permeable soil, geological conditions coupled with the solubilizing effects of low pH (caused by the presence of large amounts of battery acid), and/or a high water table. Acid rain could also depress pH, but was not cited as a major contributor to increased lead mobility in soil at the NPL sites investigated.

Soil can be contaminated by a variety of direct and indirect processes during battery breaking operations. Initially battery breaking was conducted in such a manner that the battery acid, the soluble lead in the acid, the lead sulfate sludge, metallic lead (chips, plates, dust), spongy lead, and lead dioxide were intentionally or inadvertently placed on the surface of the soil. Leaching and runoff from surface contamination and waste piles expanded the volume of the

contaminated soil. Burial of battery recycling wastes depressed the pH, thereby increasing the solubility of lead in soil water. The presence of untreated battery acid and of acid rain are potential accelerators of the mobility of lead in soil.

During secondary lead smelter operations, stack emissions and lead dusts have spread soil contamination. At some active lead smelters, dust sweepings have such high lead content (NIOSH, 1982) that they are fed back into the smelting furnaces for lead recovery.

Soils are commonly a source of health and environmental concern at lead battery recycling sites due to the many pathways of contamination: leaching from the soil into wells on or close to the site, runoff that traverses surface soil and subsequently contaminates surface water and sediments, and airborne dust that may be ingested or inhaled.

- o Groundwater -- The inorganic lead compounds associated with lead battery recycling have low aqueous solubility. However, the Maximum Contaminant Level for total lead in drinking water is currently 15 ppb -- only a small amount of lead can make the groundwater unacceptable as a drinking water source. Furthermore, reducing the pH will substantially increase the aqueous solubility of lead. One source (Watts, 1984) indicates that the solubility of lead at a pH of 4 could increase to 10,000 ppm. Therefore, if the sulfuric acid in the recycled batteries was not collected or neutralized, its discharge could elevate levels of soluble lead in the groundwater.
- o Piles -- The piles found at a site may be broken into four general types:
 - (1) Battery casing scrap piles -- These piles consist of battery casing fragments (hard rubber, ebonite, or polypropylene) with lead sulfate imbedded in cracked casing material; internal battery components (e.g., polyvinyl chloride, paper); residual lead sulfate sludge; lead dioxide; sulfuric acid; metallic lead particles; and scrap. Additional processing (cleaning, sizing, separation) may have processed the material further for on-site or off-site use for plastic recycling or fuel. Lead content of

battery scrap piles ranges from 1% to 30% total lead. Lead in TCLP leachate frequently exceeds 5 mg/L. Battery casing piles can be hazardous by virtue of their lead and lead compounds contents:

- leaching into and through the soil to groundwater or surface water (and subsequently to drinking water);
- moving to receptors via surface runoff, then to surface waters or sediments, thereby affecting drinking water or ambient water quality, and also contaminating sediments;
- migrating from the site as airborne dust; or
- directly contacting humans or animals in the food chain.

Although it has not been raised as a concern in the RI/FS, a pile of battery chips could burn, emitting lead and other contaminants to the air.

- (2) Smelter/refiner waste piles -- Although a fair amount of recycling of process by-products occurs in smelting and refining operations, various non-recyclable wastes are generated. These wastes are considered non-recyclable for technical, environmental, health, or economic reasons. They may include slag (principally silicates produced during the smelting process), matte (a metallic sulfide containing iron and lead produced during the smelting process), speiss (a mixture of metallic arsenides produced during the smelting process), dross (the scum that forms on the surface of molten metals because of oxidation or the rising impurities to the surface), air and water pollution control sludges, other residuals, and miscellaneous debris. Some of these materials may have been recycled during operations at one site, but not at another. Waste piles may also include battery debris, if some or all of the casings have not been recycled. In addition, other operations conducted at the site or landfill could have received wastes from other sites or non-battery lead scrap. These wastes are possible sources of non-battery contaminants.

Lead content in waste piles can be substantial. For example, lead content in samples from one pile ranged from 1% to 28%. Contamination emanating from these smelter/refiner waste piles has been managed with a range of care and success at various sites.

Smelter/refiner waste piles are hazardous because lead, lead compounds and other contaminants could be transported to receptors via leaching to groundwater, runoff, airborne dust, and direct contact.

- (3) Commonly re-used smelter/refiner by-product piles -- Depending upon the operation at a particular site, piles of slag, dross, speiss, matte, and pollution control sludges may have been set aside for recycling back into these or other processes. The materials may have potential value to another smelter/refiner.

These by-product piles pose the same types of health and environmental threats as for the smelter/refiner waste piles described in (2). Depending on the site, some routes of migration may have been blocked, for example by a concrete pad covering, or runoff channelling to an on-site treatment facility. Also, these piles would typically be smaller than the waste piles.

- (4) Raw materials -- There may be whole spent batteries, scrap lead, coke, scrap iron, and other smelting and refining agents present on-site. Hazardous constituents from the raw materials could potentially be transported to receptors via leaching, surface runoff, airborne dust, and direct contact.

- o Structures, buildings, and equipment -- A variety of contaminated structures, buildings, and equipment, which may be encountered at lead battery recycling sites, will require characterization. Once surface contaminant types and levels are identified, a determination must be made: whether no action, decontamination, re-use, or demolition/disposal is/are necessary, feasible, and appropriate.

Residences on and near several sites have required characterization of contaminant levels.

The following types of structures and equipment have existed near process buildings:

- shipping and receiving areas; battery breakers; acid collection sumps; battery component segregation, sizing, and cleaning machinery (e.g., conveyors, screens, cyclone separators, flotation separators, washing apparatus, and associated piping, tanks, etc.);
- kiln feedstock preparation areas; kilns (blast, reverberatory, or rotary); sweater furnaces; agglomeration furnaces; refining kettles; and associated exhaust stacks and piping, some of which may be asbestos-coated;
- air and water pollution control equipment and associated piping, tanks (perhaps containing corrosive and toxic wastewater), and mixers;
- storage bins (covered and uncovered, with and without floors) for batteries, battery scrap, slag, dross, and other process raw materials, by-products or waste;
- plastics washing and recycling equipment;
- above or below ground fuel tanks;
- sewer and wastewater lines

Process structures, buildings, and equipment have been considered hazardous because lead, lead compounds, refining agent dusts (e.g. arsenic, a carcinogen), and other contaminants could be transported to receptors via contaminated surface runoff, airborne dust, and direct contact. Recognition, evaluation, and control of risks posed by airborne dust and direct contact are particularly relevant for the protection of workers involved in site investigations, sampling, decontamination, or demolition operations.

- o Pits, ponds, lagoons, and surface water -- These locations may contain corrosive and otherwise contaminated waters and sludges. If unlined or poorly lined, they can act as a source of contamination to underlying soil and groundwater.

If precipitation exceeds evaporation, water contaminated by corrosive, soluble, and suspended solids may overflow boundaries and migrate. A similar situation could occur if an impoundment wall fails.

APPENDIX C
LAND DISPOSAL RESTRICTIONS FOR THIRD THIRD
SCHEDULE WASTES; RULE

Environmental
Protection
Agency
Land Disposal
Restrictions
for Third
Scheduled
Wastes; Rule

Friday
June 1, 1990

Part II

**Environmental
Protection Agency**

40 CFR Part 148 et al.
Land Disposal Restrictions for Third
Scheduled Wastes; Rule

BDAT TREATMENT STANDARDS FOR D007

[Nonwastewaters]

Regulated constituent	Maximum for any single grab sample, TCLP (mg/l)
Chromium (Total)	5.0

BDAT TREATMENT STANDARDS FOR D007

[Wastewaters]

Regulated constituent	Maximum for any single grab sample, total composition (mg/l)
Chromium (Total)	5.0

BDAT TREATMENT STANDARDS FOR U032

[Nonwastewaters]

Regulated constituent	Maximum for any single grab sample, TCLP (mg/l)
Chromium (Total)	0.094

BDAT TREATMENT STANDARDS FOR U032

[Wastewaters]

Regulated constituent	Maximum for any single grab sample, total composition (mg/l)
Chromium (Total)	0.32

f. Lead

D008—EP toxic for lead.

P110—Tetraethyl lead.

U144—Lead acetate.

U145—Lead phosphate.

U146—Lead subacetate.

K099—Emission control dust/sludge from secondary lead smelting.

K100—Waste leaching solution from acid leaching of emission control dust/sludge from secondary lead smelting.

(1) *D008 Wastes.* The Agency, as one alternative, proposed treatment standards below the characteristic levels for nonwastewaters and wastewaters as 0.51 mg/l TCLP and 0.04 mg/l, respectively. The Agency also proposed an option of capping the treatment standards for D008 at the characteristic level. Additional data and comments were received that indicated that the proposed levels of 0.51 mg/l TCLP and 0.04 mg/l were unachievable

for many D008 wastes on a routine basis. After detailed analysis of the available data, EPA concludes that treatment to 5.0 mg/l EP best represents the achievable treatment standard for the entire spectrum of D008 nonwastewaters. In addition, EPA is establishing the treatment standard for wastewaters at the characteristic level for the reasons stated in section III.D of the preamble.

(a) *Nonwastewaters.* The Agency proposed a cut-off concentration of 2.5% total lead as a means of distinguishing between those essentially inorganic nonwastewaters containing recyclable levels of lead and those which can be effectively stabilized. Consequently, the Agency proposed two treatability groups for lead based on the 2.5% cutoff as the Low and High Lead Subcategory. The Agency solicited comments on the use of the cutoff level and whether the 2.5% total lead gives an accurate description of lead that can be recycled from D008 nonwastewaters. Many commenters requested that the Agency not promulgate the cutoff level. In fact, many commenters suggested that it is not economically feasible to recycle lead from wastes with less than 25% lead. Many commenters (including those from secondary lead industry itself) also stated that lead concentrations are not the sole measure of recyclability. The commenters presented data that indicates that D008 nonwastewaters with greater than 2.5% total lead can often be stabilized. Therefore, the Agency has decided not to promulgate the cutoff levels and has decided not to adopt proposed high and low lead treatability groups for D008 nonwastewaters and instead to promulgate generically applicable treatment standards.

In addition, the Agency proposed and solicited comments on three options for the development of treatment standards for D008 nonwastewaters. The first option was to develop a numerical treatment standard for those D008 nonwastewaters that can be stabilized. Consequently, the Agency proposed a numerical treatment standard of 0.51 mg/l for leachable lead based on a transfer of the performance of stabilization for F006 wastes. The second option was to specify Thermal Recovery as a method of treatment as the treatment standard for D008 nonwastewaters where the lead could be recovered. The third option was to limit the treatment standard for D008 nonwastewaters to the characteristic level.

During the comment period, the Agency received D008 nonwastewater

data from various sources. Most of the data came from stabilizing specific D008 nonwastewaters. Some of the data were from the foundry industry, secondary lead smelters, the glass industry, and commercial treaters of D008 nonwastewaters. The majority of the data received by the Agency did not have the proper QA/QC, corresponding influent and effluent data, and design and operating parameters, so the Agency is hesitant to use the data in developing treatment standards. The Agency, nevertheless, evaluated all of the data to assess the range of waste variability and what standard could typically be achieved.

Stabilization data was submitted by the foundry industries by Wheland Foundry and the American Foundrymen. The untreated lead concentration ranged up to 88 mg/l leachable using the EP toxicity test. An analysis of the data indicates that the performance of the treatment system could achieve leachable levels of lead lower than the characteristic level. In fact, the highest leachable concentration of lead is 1.4 mg/l. Although these data showed that the leachable concentration of lead was below the characteristic level, the leachable level for cadmium was higher than the characteristic level. These data clearly show that the other metals in the wastes could affect the performance of stabilization for this waste. Put another way, this means (assuming proper treatment performance) that the performance of the treatment system could achieve concentration levels below the characteristic level for lead but levels higher than the characteristic level for cadmium.

Data was submitted by two glass manufacturers, Vision Ease and Ciby-Geigy Corporation. Vision Ease submitted treatment data for stabilization of ground glass particles, wastewater treatment sludges, and polishing and grinding dust. The type of binder used was hydrated lime and sodium monophosphate. The commenter indicated that these untreated wastes contained total lead concentrations greater than 2.5% and leached higher than the characteristic level; however, no actual influent concentrations were submitted. The commenter also did not submit QA/QC data. If the Agency calculated a treatment standard using the stabilized data, the standard would be the characteristic level of 5.0 mg/l measured by the EP test.

Ciby-Geigy submitted treatment data for waste produced in the manufacture of glass enamels. These wastes were produced from equipment and container washing during the manufacturing

process. These washings were treated by a wastewater treatment system that generated a sludge that exhibited the characteristic of toxicity for lead. The commenter submitted two sets of data. The first set of data was treatment of a 25.6% lead oxide sludge by stabilizing with clays, flints, and calcium chloride and then heating the waste to a maximum temperature of 1850 degrees Fahrenheit to produce a ceramic material. This ceramic material leached lead concentration ranging from 0.2 to 0.4 ppm as measured by the EP test. If the Agency calculated a treatment standard for this waste, the treatment standard would be 0.89 mg/l measured by the EP test. For this data set, there was no untreated leachable concentrations of lead, therefore the Agency cannot determine whether the waste was hazardous before treatment. The second data set contained lead oxide concentration ranging from 13% to 75%. The waste was mixed with borax and then heated to a maximum temperature of 1950 degrees Fahrenheit. This ceramic material leached lead at levels ranging from 0.2–40 ppm measured by the EP test. Of the 11 data points that were collected by the commenter, 4 of the 11 would fail the EP test. The Agency did not use these data to calculate a treatment standard, however, because each used different binder ratios. These two data sets from glass manufacturers clearly show the diversity of the waste and a difference in treatable levels. In some cases stabilization can reduce leachability of lead at, or somewhat below, the characteristic level.

The Agency received data from the Secondary Lead Smelters Association (SLSA) on the treatment of slag by stabilization. The wastes contained total concentrations of up to 10 percent lead. The types of binders that were used were portland cement, polymers, and silicates. The commenter submitted approximately 110 data points from two different plants. The binder to waste ratios ranged from 1 to 2, to 1 to 15. In the data submission, there was no QA/QC data and no corresponding influent leachable lead concentration. One data set was based on use of portland cement as a stabilizing agent with a binder to waste ratio ranging from 1 to 5, to 1 to 10. The Agency calculated a treatment standard of 2.47 mg/l was measured by the TCLP from these data. The other data set was based on the use of polymers and silicates as stabilizing agents with binder to waste ratio ranging from 1 to 5, to 4 to 10. There were approximately 94 data points, and of these data points, one was above the

characteristic level for lead. The Agency used these data to calculate a treatment standard of 4.82 mg/l as measured by the TCLP.

The Hazardous Waste Treatment Council (HWTC) submitted eight data sets for the treatment of D008 nonwastewaters. There was no QA/QC and influent leachable concentration of lead. The data set with the highest concentration of total lead was a zinc ammonium chloride solid from the manufacture of containers. This waste had a total lead concentration of 49,000 ppm. This waste was stabilized to a leachable level of lead ranging from 6.47 to 8.7 ppm as measured by the TCLP. This stabilized waste represented a volume increase ratio ranging from 1.8 to 2.5.

The data set with the next highest total lead concentration was generated from an incinerator fly ash from the aerospace industry that contained 810 ppm of total lead. Based on the data provided in the comments, this waste would not be considered characteristically hazardous due to the fact that the untreated leachable level for lead is 0.0749 ppm. This waste was treated by stabilizing with a binder to waste ratio ranging from 0.89 to 2.8. The treated leachable levels ranged from 0.1 to .27 ppm as measured by the TCLP.

The third highest data set represented data from three soils contaminated with lead and petroleum, with concentrations ranging from 29 to 561 ppm total lead. This waste contained total lead concentration of 29 ppm, and had a corresponding untreated leachable level of 6.01 ppm as measured by the TCLP, which is above the characteristic level. These soils resulted in the best treatment, with levels ranging from .066 to 0.257 ppm as measured by the TCLP. This represented a volume increase ranging from 1.6 to 3.4.

The HWTC provided three other data sets representing waste generated as water filtrate and sludge from the manufacture of conduit, as ammonium hydroxide sludge from electroplating, and as sump sludge from the reconditioning of metal drums. These wastes had total lead concentrations ranging from 234 to 460 ppm. There was no untreated TCLP data corresponding to the total lead levels. The stabilized wastes ranged in concentration from .06 to .10 ppm as measured by the TCLP. The binder to waste ratio ranged from 1.6 to 3.5.

Of these data, the waste with the highest total lead concentration shows treatment levels barely above the characteristic level of 5 ppm. These data show that a high concentration of lead

(approximately 5%) could barely be stabilized to the characteristic level (although the data are so sparse that no hard conclusions are possible). These data also show that most of the untreated wastes discussed in the HWTC comments did not exhibit a characteristic before stabilization. Also, these data highlight the diversity of D008 nonwastewaters that can be treated.

The HWTC commented on data submitted to EPA from the Secondary Lead Smelters Association (SLSA). The HWTC concluded that the treatment data support concentrations of lead below the characteristic level. The HWTC also stated that these data support the proposed BDAT treatment standard of 0.51 mg/l, or at least achieving levels below the characteristic level. The HWTC points out that agents such as fly ash, lime, and sulfide would provide for a higher degree of stabilization than just adding portland cement.

The Agency does not agree with the HWTC that these data support treatment levels significantly below the characteristic level. The data provided by SLSA clearly show that two treated data points of 87 were above the characteristic level. The Agency used the data to calculate a treatment standard of 4.82 mg/l, very close to the 5.0 mg/l characteristic level. In addition, the Agency does not agree with HWTC that other stabilizing agents may provide a higher degree of stabilization. At the least, the proposition is not self-evident. The data provided by SLSA show treatment by three types of binders and a significant range of binder to waste ratios. Using the highest binder to waste ratio for these wastes, the treated level is higher than the characteristic level. (In addition, there are issues of whether stabilization of slag is appropriate treatment. See discussion of inorganic debris in preamble section III.A.1.a.(2).)

The Agency does not believe that the data it received in response to the proposed rule represent the entire spectrum of characteristic lead nonwastewaters. Also, these data do not support the assumption that characteristic lead nonwastewaters can typically be treated to levels significantly less than the EP characteristic level. The limited amount of data does not reflect the full measure of waste variability inherent in a characteristic waste, particularly variability of matrices and lead concentrations. In addition, the commenters do not address how treatability of other metals could be affected by optimized lead treatment,

nor has EPA had the time to address this issue. With the treatment of the Vision Ease waste to 5.0 mg/l as measured by the EP and the SLSA data demonstrating treatment to 4.82 mg/l as measured by the TCLP, and data points above the characteristic level submitted by the waste treatment industry, the Agency is adopting for nonwastewater forms of D008 wastes, the treatment standard equal to 5.0 mg/l as measured by the EP procedure. The Agency is adopting this approach to address the range of variability inherent in the D008 wastes.

Because a facility may generate a waste containing lead and other metals, the TCLP (which is required for most other metals) may be used to measure compliance with this standard. EPA is not basing the standard for D008 on the TCLP, however, because that protocol is more aggressive for lead than the EP. The Agency is not sure that levels of 5.0 mg/l as measured by the TCLP are typically achievable. The TCLP can be used to demonstrate compliance. However, if the analysis shows that the waste leaches below 5.0 mg/l for lead as measured by the TCLP, then the facility has complied with the standard. If the waste leaches above 5.0 mg/l for lead, then the facility may analyze the sample using the EP procedure. (It should be noted, however, that if a waste exhibits the amended toxicity characteristic, it must still be managed in a Subtitle C facility even if it is not prohibited from land disposal).

(b) Wastewaters. In the November 22, 1989, proposed rule, the Agency proposed a treatment standard for D008 wastewaters of 0.04 mg/l based on a transfer of the performance of precipitation with lime and sulfide, filtration, and settling for K062 wastewaters. In addition, the Agency solicited comments on the approach of specifying a precipitant as a method of treatment for D008 wastewaters. Comments were solicited on whether the Agency should develop treatment standards based on data provided from the primary and secondary lead smelters industries as part of the Agency's effluent limitation guidelines program.

Many commenters questioned the Agency's technical capabilities of the transfer of the performance of the treatment system for K062 wastes as compared to D008 wastewaters. In particular, the commenters pointed out that the untreated K062 wastewaters had low concentration of lead compared to the D008 wastes as actually generated. However, commenters submitted additional data indicating that although the 0.04 mg/l for lead was

unachievable, precipitation and filtration treatment could achieve concentrations of lead in the effluent lower than the characteristic level.

In particular, the Agency received treatment data for D008 wastewaters from three sources. One set of data submitted to the Agency was from the Battery Council, Inc (BCI). These data represented a small portion of the data that was collected in the effluent limitations guidelines program for the battery and nonferrous metals point source category. BCI's contention was that if the Agency decides to develop treatment standards lower than the characteristic level for D008 wastewaters, then the Agency should base the levels on the effluent guidelines for the battery and nonferrous metals categories. The Battery Council submitted treatment data using the following treatment technologies: lime settling, lime settling and filtration, and carbonate precipitation, settling, and filtration. This data showed influent concentration levels ranging up to 300 ppm. The data showed a substantial reduction of lead and other metals from the treatment system. BCI submitted corresponding quality assurance/quality control (QA/QC) information for the data. If the Agency uses the data from the treatment system, the calculated treatment standard would be roughly 0.6 mg/l, an order of magnitude lower than the characteristic level.

In addition, the Agency received D008 wastewater data from Tricil Environmental Services, a treater of D008 and other characteristically hazardous wastewaters. However, this waste was commingled with other waste before treatment, thereby blending down such that the concentration of lead would be lower than what was actually reported. Data was submitted on the treatment of lead by precipitation with phosphate, followed by settling, and filtration. The concentration of lead in the influent before blending down ranged up to 50,000 ppm. If the Agency used all of the treatment data in order to calculate a treatment standard, the performance of the treatment system indicates that a calculated treatment standard is 0.2 mg/l, which is more than an order of magnitude lower than the characteristic level. The Agency would hesitate to use the data in developing treatment standards for D008 wastewaters due to the lack of QA/QC data and corresponding influent and effluent data. Because of the initial concentration of lead and concentrations of other dissolved metal, the Agency believes that these wastes

represent the variability associated with the characteristic wastes.

Also, the Agency received treatment data from a foundry facility treating D008 wastewater. This data represents treated wastewaters by precipitation with high magnesium lime and filtration. The lead concentration in the untreated wastewater ranged up to 276 mg/l. If the Agency used all of the treatment data, the calculated treatment standard is 0.4 mg/l, which is an order of magnitude lower than the characteristic level. For this data, the Agency evaluated the QA/QC data, the design and operating parameters, and corresponding influent concentrations.

Based on the evaluation of all of the wastewaters data received from comments, as well as the various Clean Water Act, effluent limitation guidelines and pretreatment standards regulating lead (for example, the Combined Metals Data Base and regulations for primary lead, secondary lead and battery manufacturing), the Agency concludes that well designed and well operated treatment systems can achieve total concentrations of lead lower than the characteristic level. As explained in Section III.D, however, EPA has determined not to require hazardous wastewaters to be treated to levels less than the characteristic level in order to avoid significant and potentially environmentally counterproductive disruptions to the NPDES/pretreatment and UIC programs.

In addition, many commenters suggested that the Agency not specify a precipitant as a method of treatment for D008 wastewaters. Many commenters suggest that particular precipitants may perform better depending on the characteristics of the waste. For example, Tricil Environmental points out that phosphate is a superior precipitant than carbonate or sulfate because of the low solubility of lead phosphate. The Agency agrees with the commenters and is not promulgating a precipitant as a method of treatment. In fact, the Agency is promulgating the treatment standard at the characteristic level, thereby treating and generators of D008 wastewaters may select any precipitant in order to meet the characteristic level.

(c) Lead Acid Batteries. For lead acid batteries, the Agency is promulgating a standard of "Thermal recovery of lead in secondary lead smelters (RELEAD)". (See § 268.42 Table 1 in today's rule for a detailed description of the technology standard referred to by the five letter technology code in the parentheses.) The Agency believes that virtually all of

the treaters of lead acid batteries are using a recovery process.

Incidentally, the Agency notes that lead acid batteries themselves, when stored, are not considered to be land disposed because the battery is considered to be a container (see 40 CFR 264.314(d)(3)). Battery storage, however, typically is subject to the subpart J storage standards (relating to secure storage, secondary containment in some instances, and other requirements). See subpart G of part 266.

Other commenters questioned whether the slag or matte from recovery processes would need further treatment and whether these wastes should be placed in monofills. The residuals from the recovery process are a new treatability group (i.e. the residues are not lead acid batteries) and therefore their status as prohibited or nonprohibited is determined at the point the residues are generated. Such residues would thus only be prohibited and therefore require further treatment if they exhibit a characteristic. See discussion of inorganic debris in section III.A 3.a of today's rule.

(2) *P110, U144, U145, and U146 Wastes.* The Agency proposed wastewater treatment standards for lead for P110, U144, U145, U146 based on a transfer of the performance of precipitation with lime and sulfide, filtration, and settling for K062 wastewaters. While these U and P codes represent primarily organo-lead compounds and one may consider that the transfer from an inorganic lead to an organic lead is not feasible, no comments were received indicating the lack of achievability. The Agency's judgment is that the standard is technically feasible. Therefore, the Agency is promulgating a standards for lead in P110, U144, U145, U146 wastewaters of 0.04 mg/l as proposed.

The Agency has determined that some nonwastewater forms of lead wastes including P110, U144, U146, and some D008 wastes, would need to be incinerated prior to stabilization due to the presence of high concentrations of organics in order to achieve a treatment standard based on stabilization. This is primarily because the organics typically interfere with conventional stabilization processes (particularly at concentrations exceeding 1% TOC). The Agency has data on the incineration on organic wastes containing up to 1,000 mg/kg lead (such as K087 wastes) followed by stabilization of the ash. These data indicate that the proposed standard (i.e. 0.51 mg/l leachable lead) can be

achieved for wastes that also contain significant concentrations of organics, provided the organics are destroyed by pretreatment. Lead acetate (U144) and lead subacetate (U146) are anticipated to be less difficult (or at least of similar difficulty) to treat than tetraethyl lead. The Agency is therefore promulgating the 0.04 mg/l standard for organo-lead compounds, P110, U144, and U146.

Additionally, the Agency received no comments on the feasibility of the transfer of lead in K062 wastewaters to lead phosphate U145. Therefore, the Agency will promulgate as proposed

(3) *K069.* In today's rule, the Agency is promulgating treatment standards for K069 nonwastewaters in the Calcium Sulfate Subcategory, and for wastewater forms of K069. In addition, the Agency is revoking the no land disposal based on recycling as a treatment standard for the Non Calcium Sulfate Subcategory for K069 nonwastewaters and is promulgating "Thermal Recovery of Lead in Secondary Lead Smelters (RLEAD)". See § 268.42 Table 1 in today's rule for a detailed description of the technology standard referred to by the five letter technology code in the parentheses.

For K069 wastewaters, the Agency is promulgating treatment standards for cadmium and lead. For cadmium, the treatment standard is based on the performance of chemical precipitation with lime and sulfide and sludge dewatering for K062 wastes. For lead, the treatment standard is based on the performance of chemical precipitation with magnesium hydroxide followed by clarification and sludge dewatering for D008 wastewaters. This treatment data was submitted as part of the public comment period. The Agency believes that these wastewaters better represent a K069 wastewater due to the concentration of lead (i.e. up to 300 ppm). The Agency believes that the performance of both technologies can achieve the regulated concentration due to the fact that both precipitating agents are hydroxides.

BDAT for K069 nonwastewaters in the Calcium Sulfate Subcategory is stabilization. The Agency believes that there is only one generator of this waste and that this waste cannot be directly recycled to recover lead. The waste characterization data from the one generator indicated that this waste contains metal constituents such as cadmium and lead. The metal concentrations range up to 3300 ppm.

For the K069 nonwastewaters in the Calcium Sulfate Subcategory, the

Agency is transferring the performance of stabilization of K061 to K069 nonwastewaters. This is a technically feasible transfer because the K061 waste is a more difficult waste to treat. In fact, the lead concentrations in K061 waste ranges up to 20,300 ppm thus, the performance of the treatment system can be legitimately transferred.

(4) *K100.* In today's rule, the Agency is promulgating treatment standards for wastewaters and nonwastewater forms of K100 wastes as proposed. For cadmium and total chromium in K100 wastewaters, treatment standards are based on a transfer of the performance of chromium reduction followed by lime and sulfide precipitation, and dewatering for K062 wastes. For lead in K100 wastewaters, treatment standard is based on the performance of chemical precipitation with magnesium hydroxide followed by clarification and sludge dewatering for D008 wastewaters. The Agency believes that both technologies can achieve the concentration of the regulated constituents due to the fact that both precipitating agents are hydroxides. For K100 nonwastewaters treatment standards are based on the transfer of the performance of stabilization for F006 wastes.

Treatment standards for K100 wastes were originally scheduled to be promulgated as part of the Third Third rulemaking. However, a treatment standard of "No Land Disposal Based on No Generation" for K100 nonwastewaters was promulgated on August 8, 1988 and subsequently revised on May 2, 1989 (54 FR 18836) to be applicable only to "Nonwastewater forms of these wastes generated by the process described in the listing description and disposed after August 17, 1988, and not generated in the course of treating wastewater forms of these wastes (Based on No Generation)." The Agency received no comments on the treatment standards for K100 wastes; therefore, the Agency is promulgating as proposed.

BDAT TREATMENT STANDARDS FOR D008 (Nonwastewaters)

Regulated constituent	Maximum for any single grab sample, EP (mg/l)
Lead	50

BDAT TREATMENT STANDARDS FOR D008

[Wastewaters]

Regulated constituent	Maximum for any single grab sample, total composition (mg/l)
Lead	5.0

BDAT TREATMENT STANDARDS FOR D008

[Lead Acid Batteries]

Thermal recovery (RLEAD) of lead in secondary lead smelters

BDAT TREATMENT STANDARDS FOR P110, U144, U145, AND U146

[Wastewaters]

Regulated constituent	Maximum for any single grab sample, total composition (mg/l)
Lead	0.040

BDAT TREATMENT STANDARDS FOR P110, U144, U145, AND U146

[Nonwastewaters]

Regulated constituent	Maximum for any single grab sample, TCLP (mg/l)
Lead	0.51

BDAT TREATMENT STANDARDS FOR K069

[Wastewaters]

Regulated constituent	Maximum for any single grab sample, total composition (mg/l)
Cadmium	1.6
Lead	0.51

BDAT TREATMENT STANDARDS FOR K069
CALCIUM SULFATE SUBCATEGORY

[Nonwastewaters]

Regulated constituent	Maximum for any single grab sample, TCLP (mg/l)
Cadmium	0.14
Lead	0.24

BDAT TREATMENT STANDARDS FOR K069
NON-CALCIUM SULFATE SUBCATEGORY

[Nonwastewaters, Revised From No Land Disposal]

Thermal recovery of lead in secondary lead smelters (RLEAD)

BDAT TREATMENT STANDARDS FOR K100

[Wastewaters; Revised From No Land Disposal]

Regulated constituent	Maximum for any single grab sample, total composition (mg/l)
Cadmium	1.6
Chromium (Total)	0.32
Lead	0.51

BDAT TREATMENT STANDARDS FOR K100

[Nonwastewaters, Revised From No Land Disposal]

Regulated constituent	Maximum for any single grab sample, TCLP (mg/l)
Cadmium	0.066
Chromium (Total)	5.2
Lead	0.51

* See § 268.42 Table 1 in today's rule for a detailed description of the technology standard referred to by the five letter technology code in parentheses

g. Mercury

D009—EP toxic for mercury.

K071—Brine purification muds from the mercury cell process in chlorine production, where separately prepurified brine is not used.

K106—Wastewater treatment sludges from the mercury cell process in chlorine production.

P065—Mercury fulminate.

P092—Phenylmercury acetate.

U151—Mercury.

EPA is today promulgating treatment standards for D009, K106, P065, P092, and U151. EPA has revised the proposed regulatory approach for some of these wastes in response to comment. EPA is also withdrawing the proposed revisions for K071 nonwastewaters. These wastes are described fully in the respective Listing Background Documents.

(1) *Review of BDAT for Nonwastewaters.* EPA identified thermal recovery processes, acid leaching, stabilization, and incineration as BDAT for mercury wastes. Commenters questioned whether thermal processing of mercury should be the basis (or the exclusive basis) for the treatment standard. Use of thermal processing raises issues of cross-media

transfer of mercury, as well as the environmental benefit of thermal processing over stabilization or land disposal. Other comments questioned the amenability of mercury sulfide wastes to stabilization as well as EPA's proposed restrictions on co-disposal of mercury wastes with alkaline wastes. The stabilization comments and the co-disposal issues are addressed in section III.A.3.a.

Multimedia issues raised by thermal processing of mercury materials involve the potential transfer of mercury and sulfur dioxide from the retorting/roasting chambers to downstream air pollution control devices (APCD) and potentially to environmental media (e.g., air to water). Specifically, commenters felt that EPA had not properly addressed the issue of mercury air emissions from retorting and urged EPA to quantify mercury emissions prior to determining whether roasting or retorting represents BDAT for mercury and sulfide wastes (i.e., K106).

The Agency acknowledges the legitimacy of the commenters' concerns, which the Agency shares. The Agency discussed the issue of air controls for mercury retorting at 54 FR 48501. In addition, the Agency provided calculations in the administrative record for the proposed rule of the potential amounts of sulfur dioxide emissions to the air that could result from the retorting or roasting of mercury sulfide wastes such as K106, based on available performance data from a facility thermally processing cinnabar ores. EPA also included the document entitled, "Review of National Emission Standards (NESIAPs) for Mercury" (EPA 450/3-84-014, 1984) in the proposed administrative record. In this 1984 document, EPA provided quantitative analysis for the potential of mercury air emissions from several industrial operations that include the thermal processing of cinnabar ores as well as the retorting of mercury containing wastes.

The available air emission information shows that both mercury and sulfur dioxide emissions can be effectively controlled by well designed and well operated air pollution control devices that allow for the recovery of valuable mercury. Based on available air emission information, performance data from the thermal processing of cinnabar ores, and performance data from the retorting/roasting of mercury wastes, EPA determined that retorting/roasting represent BDAT for mercury wastes. EPA reaffirms this determination in today's rule. In order to assure that air emissions from mercury

EPA is not granting arsenic wastewaters a capacity variance.

(b) Barium Wastes. For D005 and P013 wastewaters, EPA is promulgating concentration standards based on chemical precipitation; for D005 and P013 (except as indicated below) nonwastewaters, EPA is promulgating concentration standards based on stabilization.

For P013 nonwastewaters with high levels of organics, EPA is requiring that these wastes be incinerated prior to stabilization. Sufficient capacity exists to treat surface-disposed D005 and P013 wastes. Therefore, EPA is not granting a national capacity variance for them.

(c) Cadmium Wastes. For D006 wastes, EPA is promulgating treatment standards for three categories: wastewaters, nonwastewaters, and cadmium batteries.

For D006 wastewaters, EPA is promulgating concentration standards based on chemical precipitation. For D006 nonwastewaters, EPA is promulgating concentration standards based on stabilization or metal recovery. EPA believes that sufficient capacity exists to treat surface-disposed cadmium nonwastewaters and wastewaters. Therefore, EPA is not granting a national capacity variance for them.

For D006 cadmium batteries, EPA is promulgating thermal recovery as the method of treatment. In the proposed rule, EPA proposed granting D006 cadmium batteries a national capacity variance due to a lack of identified recovery capacity. During the public comment period, two commenters identified available commercial cadmium battery recovery capacity (these comments were available for reply comments). EPA contacted these commenters to verify their capacity. Based on these contacts, EPA received additional information and determined that adequate capacity for treating surface-disposed cadmium batteries exists. Therefore, EPA is not granting D006 cadmium batteries a national capacity variance.

(d) Chromium Wastes. For D007 chromium and U032 (calcium chromate) wastewaters, EPA is promulgating concentration standards based on chromium reduction followed by chemical precipitation; for D007 and U032 nonwastewaters, EPA is promulgating concentration standards based on chromium reduction followed by stabilization. EPA believes sufficient treatment capacity exists for the volume of these wastes. Therefore, EPA is not granting a national capacity variance for them.

(e) Lead Wastes.

D008—EP toxic for lead

P110—Tetraethyl lead

U144—Lead acetate

U145—Lead phosphate

U146—Lead subacetate

K069—Emission control dust/sludge from secondary lead smelting

K100—Waste leaching solution from acid leaching of emission control dust/sludge from secondary lead smelting

For D008 wastes, EPA is promulgating standards for three categories: nonwastewaters, wastewaters, and lead-acid batteries. For D008 nonwastewater lead wastes, EPA is promulgating concentration standards based on stabilization, except where the waste contains significant concentrations of organics. In this case, these wastes may need to be incinerated prior to stabilization. For D008 wastewaters, EPA is promulgating concentration standards based on chemical precipitation. EPA believes sufficient capacity exists for surface-disposed D008 wastewaters and nonwastewaters. Therefore, EPA is not granting a national capacity variance for D008 wastewaters and nonwastewaters, with the exceptions noted below.

EPA is promulgating thermal recovery as the method of treatment for lead-acid batteries. Secondary lead smelters have stated that they store these wastes in piles prior to recovery. EPA has indicated in a previous rulemaking that the shells surrounding lead-acid batteries are considered to be storage containers (see 47 FR 12318 and 40 CFR 264.314(f)(3)). Therefore, to the extent that lead-acid battery storage meets all the requirements of the LDR storage prohibitions at 40 CFR 268.50, such storage is permissible.

In the proposed rule, EPA solicited comments on the management of other D008 lead material at secondary smelters. EPA also indicated that storage of lead materials in waste piles prior to smelting is a form of land disposal, and as such these staging areas are subject to the statutory prohibitions. During the public comment period, EPA received several comments from the secondary lead smelting industry regarding the storage of battery parts prior to smelting. Several commenters expressed concern that EPA's determination that staging piles are a form of land disposal could force them to close or operate out of compliance while staging piles are replaced by tanks (assuming tank storage is viable). As a result of these comments, EPA contacted several secondary smelters to assess the potential capacity impact of required staging area reconstruction. Because of the large volume of batteries currently processed at smelting facilities whose

continued storage operation remains in question, EPA is granting a two-year national capacity variance to allow storage of the batteries preceding smelting. EPA is also reconsidering whether certain forms of battery parts storage meet the meaning of "land disposal" under section 3004(k). In particular, if battery parts (or other wastes) are stored in 3-sided tank-like devices on concrete inside buildings (the present storage method of some secondary lead smelters) the Agency is not certain that the language and policies underlying section 3004(k) warrant designating such practice as "land disposal." Given the two-year national capacity variance in this rule, however, the Agency need not make a final decision on this point in this rulemaking.

For P110, U144, U145, and U146 wastes, EPA is promulgating concentration standards based on chemical oxidation followed by chemical precipitation for wastewaters, and stabilization for nonwastewaters. P110, U144, U145, and U146 nonwastewaters containing significant concentrations of organics may require incineration prior to stabilization. EPA believes sufficient capacity exists for the small volume of these wastes that are surface-disposed; therefore, EPA is not granting a national capacity variance for them.

EPA is revoking the no land disposal standard based on recycling standard promulgated in the First Third rule for the non-calcium sulfate subcategory for K069 nonwastewaters. For K069 calcium sulfate nonwastewaters, EPA is promulgating concentration standards based on stabilization. For K069 non-calcium sulfate nonwastewaters, EPA is promulgating recycling as the method of treatment. For K069 wastewaters, EPA is promulgating concentration standards based on chemical precipitation. EPA believes adequate capacity exists to treat the volume of surface-disposed K069 wastewaters and nonwastewaters, therefore, EPA is not granting a capacity variance for them.

For K100 nonwastewaters, EPA is revoking the no land disposal standard based on the "no generation standards" promulgated in the First Third rule. Today, EPA is promulgating concentration standards based on stabilization for the nonwastewaters and chemical precipitation for the wastewaters. EPA believes adequate capacity exists to treat the volume of surface-disposed K100 wastes. Therefore, EPA is not granting a capacity variance for them.

APPENDIX D
CLEANUP LEVEL FOR LEAD IN GROUNDWATER



UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
WASHINGTON, D.C. 20460

OFFICE OF
SOLID WASTE AND EMERGENCY RESPONSE

MEMORANDUM

JUN 21 1990

SUBJECT: Cleanup Level for Lead in Ground Water

FROM: Henry L. Longest, Director
Office of Emergency and Remedial Response

Bruce M. Diamond, Director
Office of Waste Programs Enforcement

TO: Patrick M. Tobin, Director
Waste Management Division, Region IV

PURPOSE

This memorandum addresses the issue of a protective cleanup level for lead in ground water usable for drinking water, which is a major concern for several Superfund sites in Region IV.

OBJECTIVE

The objective of this memorandum is to recommend a final cleanup level for lead in ground water usable for drinking water which will meet the CERCLA requirement that all Superfund remedies be protective of human health and the environment.

BACKGROUND

The current Maximum Contaminant Level (MCL) for lead is 50 ppb and was promulgated in 1975 as an interim national primary drinking water regulation (NPDWR) under the Safe Drinking Water Act (SDWA). On November 13, 1985, the Agency began the process of revising this standard by proposing a Maximum Contaminant Level Goal (MCLG) as required by the SDWA (50 FR 46936).

On August 18, 1988 EPA proposed an MCLG for lead at zero and an MCL of 5 ppb (53 FR 31516). Also, since the primary cause of lead-contaminated drinking water is corrosion of lead-bearing pipes in public water supply (PWS) distribution systems and/or household plumbing, the proposed rule would direct PWSS to meet treatment technique requirements and to deliver public education to reduce and minimize exposures to lead in drinking water.

These requirements would be triggered when an action level is exceeded at consumers' taps throughout the water distribution system. The Agency proposed an action level of 10 ppb, on average, to trigger corrosion control and public education. Another lead action level of 20 ppb, measured at the 95 percentile of samples, was proposed as a trigger for public education.

The Agency is considering promulgation of treatment technique requirements which may include additional source water treatment, lead service connection replacement, and public education if lead concentrations at the tap exceed an action level. Any such technological treatment targets will provide substantial health protection. A final rule is being worked on, and is scheduled for promulgation in December 1990.

DISCUSSION

No cancer potency factor or reference dose has been promulgated for lead; therefore, an assessment of protective levels of lead in ground water that may be used for drinking water purposes will be based on current data. The Agency has identified 10 micrograms per deciliter (ug/dl) as a blood lead level of concern in young children. Blood lead levels above 10 ug/dl are associated with increased risks of potentially adverse effects on neurological development and diverse physiological functions.

Attached is available data that support the recommended final cleanup level for lead in drinking water at Superfund sites. This information includes the June 15, 1990, EPA draft final report entitled, "Contributions To a Risk Assessment For Lead in Drinking Water" and the June 1986, EPA draft final report entitled, "Air Quality Criteria for Lead" (Volume III of IV, p. 11-129). Based on these data, lead levels in drinking water of 15 ppb and lower should correlate to blood lead levels below the concern level of 10 ug/dl. The Agency estimates that steady exposure to a water lead concentration of 15 ppb would contribute, at most, 2-3 ug/dl to a child's blood lead. Sources of lead other than drinking water (e.g. food, air, soil, dusts) typically contribute approximately 4-5 ug/dl to children's blood lead. Accounting for the variability inherent in childhood behavior, nutrition, and physiology, it is estimated that total lead exposure, given 15 ppb in drinking water, would result in blood lead levels below 10 ug/dl in

roughly 99 percent of young children who are not exposed to excessive lead paint hazards or heavily contaminated soils. Therefore, a 15 ppb cleanup level would provide substantial health protection for the majority of young children. Most of the remaining lead problem will continue to be contaminated soils and old lead-painted housing.

In an April 10, 1989, Federal Register notice (54 FR 14316), EPA announced the availability of a guidance document and testing protocol entitled, "Lead in School's Drinking Water," to assist schools in determining the source and degree of lead contamination in school drinking water supplies and how to remedy such contamination. That document, which is also attached, recommends that schools take remedial steps whenever the lead level at any drinking water outlet exceeds 20 ppb.

RECOMMENDATION

Based on a review of these and other studies, it is recommended that a final cleanup level of 15 ppb for lead in ground water usable for drinking water is protective. If water used for drinking purposes subsequent to achieving the cleanup goal in the aquifer may need further treatment to account for lead contributions related to the distribution of water through pipes, the responsibility for this additional treatment or the replacement of lead-bearing water pipes lies with the persons who are using or distributing the water. A concentration of lead of 15 ppb in drinking water should generally correlate with a blood lead level below the concern level of 10 ug/dl. In some situations, lower cleanup levels may be appropriate based on site-specific factors, such as multiple pathways of exposure caused by lead from the site.

If the remedial action will include treatment and supplying water directly to the public for drinking water consumption, compliance with a 15 ppb action level should be met at 90 percent of the taps to ensure that the remedy is protective. When the lead NPDWR is promulgated, applicable or relevant and appropriate requirements of that rule should be met.

FUTURE GUIDANCE

After promulgation of the lead NPDWR, guidance will be issued discussing those provisions of the rule that may be applicable or relevant and appropriate for Superfund actions.

For further information, please contact Tish Zimmerman at FTS 382-2461 or Neilima Senjalia at FTS 475-7027.

DISCLAIMER

The recommendations in this document are intended solely as guidance. They are not intended and cannot be relied upon to create any rights, substantive or procedural, enforceable by any party in litigation with the United States. EPA reserves the right to act at variance with these recommendations and to change them at any time without public notice.

Attachments

cc: Directors, Waste Management Division, Regions I, V, VII, VIII
Directors, Emergency and Remedial Response Division, Region
II
Directors, Hazardous Waste Management Division, Regions III,
VI, IX
Directors, Hazardous Waste Division, Region X

APPENDIX E
INTERIM GUIDANCE ON ESTABLISHING SOIL LEAD CLEANUP
LEVELS AT SUPERFUND SITES



UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
WASHINGTON, D.C. 20460

OFFICE OF
SOLID WASTE AND EMERGENCY RESPONSE

SEP 1 1988

OSWER Directive #9355.4-02

MEMORANDUM

SUBJECT: Interim Guidance on Establishing Soil Lead Cleanup Levels at Superfund Sites.

FROM: Henry L. Longest II, Director *H. L. Longest II*
Office of Emergency and Remedial Response
Bruce Diamond, Director *B. Diamond*
Office of Waste Programs Enforcement

TO: Directors, Waste Management Division, Regions I, II, IV, V, VII and VIII
Director, Emergency and Remedial Response Division, Region II
Directors, Hazardous Waste Management Division, Regions III and VI
Director, Toxic Waste Management Division, Region IX
Director, Hazardous Waste Division, Region X

PURPOSE

The purpose of this directive is to set forth an interim soil cleanup level for total lead, at 500 to 1000 ppm, which the Office of Emergency and Remedial Response and the Office of Waste Programs Enforcement consider protective for direct contact at residential settings. This range is to be used at both Fund-lead and Enforcement-lead CERCLA sites. Further guidance will be developed after the Agency has developed a verified Cancer Potency Factor and/or a Reference Dose for lead.

BACKGROUND

Lead is commonly found at hazardous waste sites and is a contaminant of concern at approximately one-third of the sites on the National Priorities List (NPL). Applicable or relevant and appropriate requirements (ARARs) are available to provide cleanup levels for lead in air and water but not in soil. The current

National Ambient Air Quality Standard for lead is 1.5 ug/m³. While the existing Maximum Contaminant Level (MCL) for lead is 50 ppb, the Agency has proposed lowering the MCL for lead to 10 ppb at the tap and to 5 ppb at the treatment plant⁽¹⁾. A Maximum Contaminant Level Goal (MCLG) for lead of zero was proposed in 1988⁽²⁾. At the present time, there are no Agency-verified toxicological values (Reference Dose and Cancer Potency Factor, ie., slope factor), that can be used to perform a risk assessment and to develop protective soil cleanup levels for lead.

Efforts are underway by the Agency to develop a Cancer Potency Factor (CPF) and Reference Dose (RfD), (or similar approach), for lead. Recently, the Science Advisory Board strongly suggested that the Human Health Assessment Group (HHAG) of the Office of Research and Development (ORD) develop a CPF for lead, which was designated by the Agency as a B2 carcinogen in 1988. The HHAG is in the process of selecting studies to derive such a level. The level and documentation package will then be sent to the Agency's Carcinogen Risk Assessment Verification Exercise (CRAVE) workgroup for verification. It is expected that the documentation package will be sent to CRAVE by the end of 1989. The Office of Emergency and Remedial Response, the Office of Waste Programs Enforcement and other Agency programs are working with ORD in conjunction with the Office of Air Quality Planning and Standards (OAQPS) to develop an RfD, (or similar approach), for lead. The Office of Research and Development and OAQPS will develop a level to protect the most sensitive populations, namely young children and pregnant women, and submit a documentation package to the Reference Dose workgroup for verification. It is anticipated that the documentation package will be available for review by the fall of 1989.

IMPLEMENTATION

The following guidance is to be implemented for remedial actions until further guidance can be developed based on an Agency verified Cancer Potency Factor and/or Reference Dose for lead.

Guidance

This guidance adopts the recommendation contained in the 1985 Centers for Disease Control (CDC) statement on childhood lead poisoning⁽³⁾ and is to be followed when the current or predicted land use is residential. The CDC recommendation states that "...lead in soil and dust appears to be responsible for blood levels in children increasing above background levels when the concentration in the soil or dust exceeds 500 to 1000 ppm". Site-specific conditions may warrant the use of soil cleanup levels below the 500 ppm level or somewhat above the 1000 ppm level. The administrative record should include background documents on the toxicology of lead and information related to site-specific conditions.

The range of 500 to 1000 ppm refers to levels for total lead, as measured by protocols developed by the Superfund Contract Laboratory Program. Issues have been raised concerning the role that the bioavailability of lead in various chemical forms and particle sizes should play in assessing the health risks posed by exposure to lead in soil. At this time, the Agency has not developed a position regarding the bioavailability issue and believes that additional information is needed to develop a position. This guidance may be revised as additional information becomes available regarding the bioavailability of lead in soil.

Blood-lead testing should not be used as the sole criterion for evaluating the need for long-term remedial action at sites that do not already have an extensive, long-term blood-lead data base⁽¹⁾.

EFFECTIVE DATE OF THIS GUIDANCE

This interim guidance shall take effect immediately. The guidance does not require that cleanup levels already entered into Records of Decisions, prior to this date, be revised to conform with this guidance.

¹ In one case, a biokinetic uptake model developed by the Office of Air Quality Planning and Standards was used for a site-specific risk assessment. This approach was reviewed and approved by Headquarters for use at the site, based on the adequacy of data (due to continuing CDC studies conducted over many years). These data included all children's blood-lead levels collected over a period of several years, as well as family socio-economic status, dietary conditions, conditions of homes and extensive environmental lead data, also collected over several years. This amount of data allowed the Agency to use the model without a need for extensive default values. Use of the model thus allowed a more precise calculation of the level of cleanup needed to reduce risk to children based on the amount of contamination from all other sources, and the effect of contamination levels on blood-lead levels of children.

REFERENCES

1. 53 FR 31516, August 18, 1988.
2. 53 FR 31521, August 18, 1988.
3. Preventing Lead Poisoning in Young Children, January U.S. Department of Health and Human Services, Center for Disease Control, 99-2230.

APPENDIX F

U.S. PRIMARY AND SECONDARY LEAD SMELTERS

TABLE F-1. LIST OF U.S. PRIMARY AND SECONDARY LEAD SMELTERS

Primary Smelters

ASARCO	Omaha, NE
ASARCO	Glover, MO
ASARCO	E. Helena, MT
Doe Run	Boss, MO
Doe Run	Herculaneum, MO

Secondary Smelters

ALCO Metals	Los Angeles, CA
East Penn Mfg.	Lyon Station, PA
Exide Corp.	Reading, PA (General Battery Corp.)
Exide Corp.	Muncie, IN
Exide Corp.	Dallas, TX (Dixie Metals Corp.)
GNB, Inc.	Columbus, GA
GNB, Inc.	Frisco, TX
GNB, Inc.	Los Angeles, CA
General Smelting & Refining	Cottage Grove, TN
Gopher Smelting & Refining	Minneapolis, MN
Gulf Coast Lead	Tampa, FL
Interstate Lead	Leeds, AL
Master Metals	Cleveland, OH
Pacific Chloride	Columbus, GA
Refined Metals	Beech Grove, IN
Refined Metals	Memphis, TN
Ross Metals	Rossville, TN
Roth Brothers	Syracuse, NY
RSR Corp.	Middletown, NY
RSR Corp.	Indianapolis, IN
RSR Corp.	Los Angeles, CA
Sanders Lead	Troy, AL
Schuykill Metals	Baton Rouge, LA
Schuykill Metals	Cannon Hollow, MO
Standard Industries	San Antonio, TX (Reliable Battery)
Tara Corp.	Granite City, IL

Source: Fox, Weinberg, and Bennett, Washington, D.C.; U.S. Bureau of Mines.

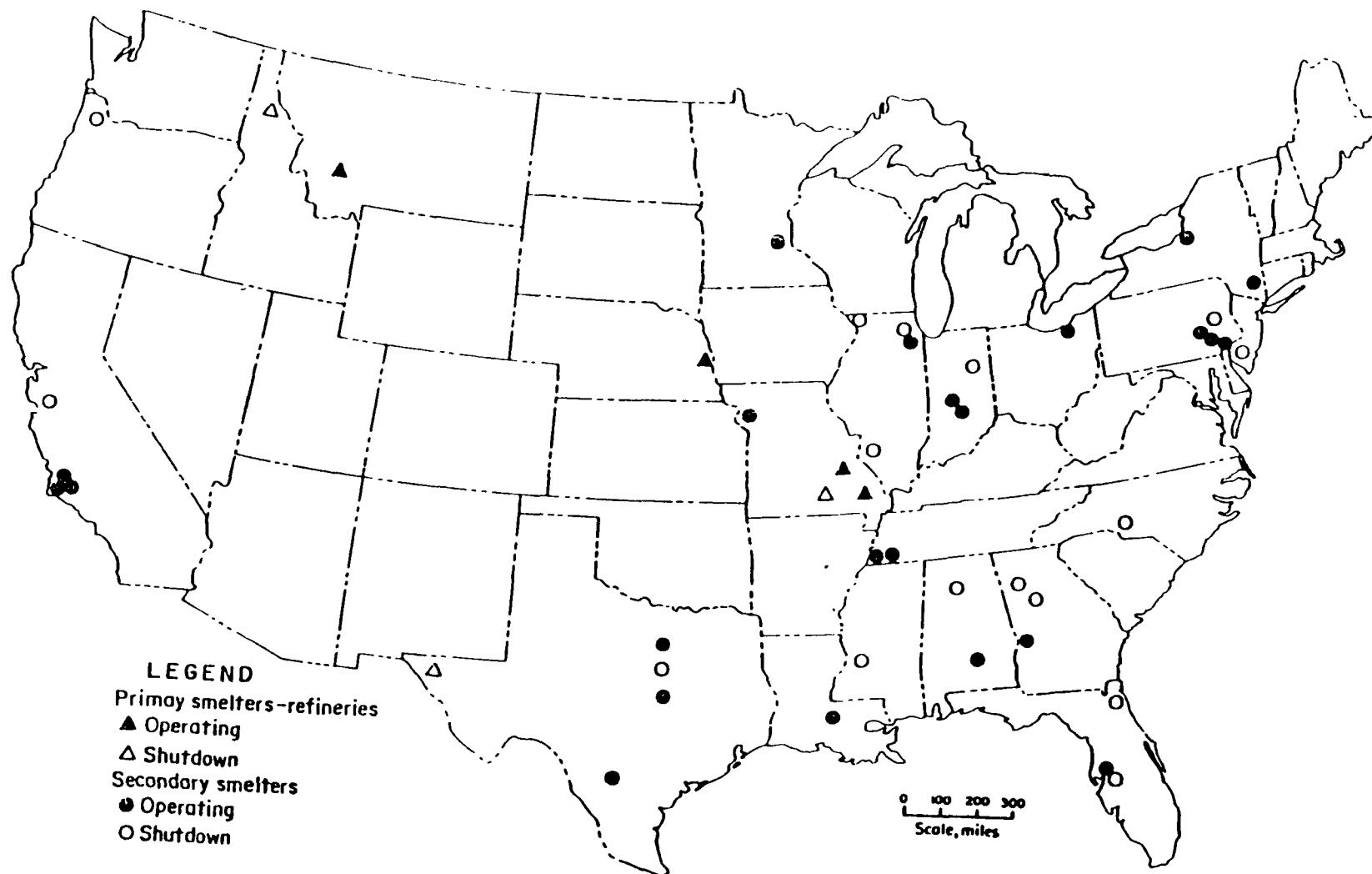


Figure F-1. Location of primary and secondary smelters.

Source: Isherwood, et al, U.S. Bureau of Mines,
Open File Report 55-88, 1988.