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SUPERFUND INNOVATIVE
TECHNOLOGY EVALUATION

Emerging Technology Summary

Reclamation of Lead from Superfund Waste Material Using Secondary Lead Smelters

Stephen W. Paff and Brian E. Bosilovich

Hundreds of sites across the United States are contaminated with lead from various sources. Through a Cooperative Agreement with the U.S. Environmental Protection Agency's (EPA) Risk Reduction Engineering Laboratory, the Center for Hazardous Materials Research (CHMR), in conjunction with a major secondary lead smelter, has demonstrated that secondary lead smelters may be used economically to reclaim lead from a wide range of lead-containing materials frequently found at Superfund sites. Such materials include battery case materials, lead dross, and other debris containing greater than 1% lead.

During the study, CHMR and the smelter reclaimed lead from five sets of materials, including two Superfund sites containing primarily battery cases and one battery breaker/smelter site with a variety of lead-containing materials. Between 4 and 1500 tons of materials from each of these sites were excavated or collected and processed at the smelter, while the research team assessed the effects on furnace operation and performance. Two additional sets of materials, one from the demolition of a house containing lead-based paint and the other from work on a bridge coated with lead paint, were also processed in the smelter. The results showed that it was technically feasible to use the secondary lead smelter to reclaim lead from all of the materials.

CHMR also assessed the economics of using secondary lead smelters to reclaim lead from Superfund sites and developed a method for estimating the cost of reclaiming lead. This method develops cost as a function of material excavation, transportation, and processing costs combined with cost benefits received by the smelter (in the form of recovered lead, reduced fuel usage, and/or reduced iron usage). The total remediation costs using secondary lead smelters for the sites and materials studied varied between $35 and $374/ton, based on a conservative market price for lead. The costs were primarily a function of lead concentration, the market price for lead, distance from the smelter, and the amount of materials that became incorporated into slag from the process, although other factors affected the economics as well. Materials with high concentrations of lead were significantly less expensive to remediate than those with low concentrations. The cost to remediate materials that left few slag residues in the

furnace was significantly lower than the cost to remediate materials that contained significant slagging components.

This Project Summary was developed by EPA's Risk Reduction Engineering Laboratory, Cincinnati, OH, to announce key findings of this SITE Emerging Technology Project that are fully documented in a separate report of the same title (see Project Report ordering information at back).

Introduction

Lead is used in the production of various consumer and commercial items, from automobile and equipment batteries to paints to crystal. This widespread use has made it one of the most frequent contaminants at sites on the National Priorities List (NPL). The most common current treatment of lead contaminated wastes at Superfund sites is immobilization, either onsite or in a landfill. Remedial approaches involving recovery of lead are often preferred over immobilization, which wastes usable lead. One such remedial approach is the use of secondary lead smelters for recovery.

The objective of this project was to determine the technical and economical feasibility of processing select lead-containing wastes at secondary smelters. Five types of waste materials were processed a single secondary smelter in different tests. The materials tested include material from three Superfund sites (the Tonolli site in Nesquehoning, PA; the Hebelka site in Weisenburg County, PA; and the NL Industries site in Pedricktown, NJ) and two other sources (demolition material and abrasive bridge blasting material). The report summarized here presents the activities conducted, the experiments performed, and the results obtained.

Process Description

The overall process for the project involves acquiring the waste material, transporting it to a secondary smelter, blending it with typical feeds, and smelting it to reclaim usable lead. A schematic of this process is shown in Figure 1, and the individual steps are described in more detail below.

Material Acquisition, Preprocessing, and Transportation

The first step in reclaiming lead from Superfund wastes is acquiring and transporting the material to one smelter. Generally, this involves excavation or collection, pre-processing, and transport to the smelter. The lead-containing waste material is typically excavated from lead-acid battery Superfund sites. Materials may be collected from other sources, such as bridge blasting or demolition operations.

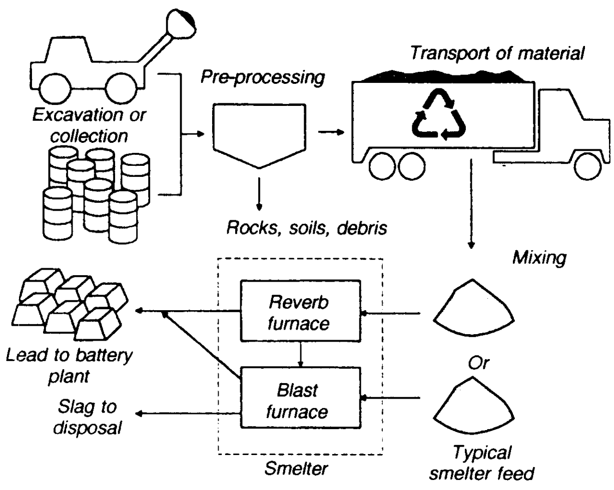

Figure 1. *Schematic of reclamation process.*

Some materials often require some type of processing before entering the furnace. Preprocessing includes screening to remove soil, large stones, or non-contaminated debris. Soil cannot be processed through a secondary smelter. Larger debris (>12 in.) is also removed because large material tends to remain unburnt in reverberatory furnaces. This causes sluggish performance and slows productivity by the reverberatory furnaces. Preprocessing can be done at the site or at the smelter, depending on which is more cost efficient.

Blending with Typical Furnace Feeds

Once the material arrives at the secondary lead smelter, it is blended with typical feed before processing through the smelter's reverberatory and blast furnaces. This mixing prevents problems associated with the layering of the test material in the furnaces. Typical blend ratios range from 10% to 50% by weight, and are determined based on treatability tests and other factors, such as lead, sulfur, iron, or ash content.

Smelting Process

As part of normal secondary lead smelting operations, spent batteries received at the smelter are crushed to release the sulfuric acid and then processed through a sink/float system to separate the battery cases. Dual reverberatory furnaces at the smelter are charged with material from the sink/float system as well as other lead-containing material. These furnaces are fueled with natural gas and oxygen. Reverberatory furnaces are tapped for slag, which typically contains 60% to 70% lead, and a soft (pure) lead product.

Dual blast furnaces are charged with the slag generated from the reverberatory furnaces as well as other lead-containing materials. These furnaces are fueled by coke and oxygen-enriched air. Iron and limestone are added as fluxing agents to enhance furnace production. The blast furnaces are tapped continuously to remove lead and intermittently to remove the slag. The blast slag, which contains primarily silica and iron oxides, is transported to an offsite landfill for disposal.

Lead produced in the blast and reverberatory furnaces is transferred to the refining process where additional metals are added to make specific lead alloys. The lead is then pumped to the casting operations where it is molded into ingots for use in the manufacture of new lead-acid batteries.

Test Materials

Materials from three Superfund sites as well as two additional sets of lead-containing materials were processed during this project. Table 1 presents a summary of the materials tested and the evaluations. A short description of each of the five evaluations follows the table. The feed rates are presented as weight ratios of test material to total furnace feed.

Tonolli Superfund Site

The Tonolli site was a battery breaking and smelting facility located in Nesquehoning, PA. Piles of ebonite rubber and polypropylene battery case pieces

Table 1. *Summary of Demonstration Sites*

Test Parameter	*Tonolli Site*	*Hebelka Site*	*Demolition Waste*	*NL Industries site*	*PennDOT*
Site Type	*Integrated battery breaker, smelter, and lead refiner*	*Automobile junk and salvage yard*	*Not applicable*	*Integrated battery breaker, smelter, and refiner with onsite landfill*	*Bridge blasting operation to remove lead paint site landfill*
Length of Test	*5 days*	*1 day*	*2 days*	*Preliminary: 4 days* *Full: 3 months*	*1 day*
Material Type	*Rubber and plastic battery cases*	*Rubber and plastic battery cases with some soil*	*Demolition debris coated with lead paint*	*Lead slag, debris, dross, ingots; battery case pieces, baghouse bags, pallets, cans*	*Iron shot bridge blasting material*
Amount Processed	*84 tons*	*8 tons*	*4 tons*	*Preliminary test: 370 tons* *Full-scale test: 1200 tons*	*6 tons*
Percent Test Material in Feed	*10%*	*17%*	*5%*	*20% to 50%*	*13%*
Lead Concentration	*3.5%*	*14.7%*	*1%*	*Preliminary: 57%* *Full: 30% to 50%*	*3.2%*
Preprocessing	*None*	*Reduced to less than 1/4 in. in a hammermill*	*Reduced in size with a pallet shredder*	*Large pieces removed for processing in the blast furnace*	*None*
Difficulties Encountered	*Attempted to process in reverb, but material was too large*	*None*	*Initial feed ratio was too high*	*Reverb could not process 100% waste material*	*Material was too moist to process in reverb furnace*

were tested, without any preprocessing. The material had an average lead concentration of 3.5%. Approximately 84 tons of material were fed at a ratio of 10% through a reverberatory and blast furnace. The material was too large to be readily processed in the reverberatory furnace but was successfully processed in the blast furnace.

Hebelka Superfund Site

The Hebelka site was a former automobile junk and salvage yard located in Weisenburg Township, PA. The site contained battery case debris mixed with some soil that had an average lead concentration of 14.7%. Approximately 20 yd^3 of material were transported to the smelter. This material was first reduced in size to less than 1/4-in. with a hammermill. The material was successfully fed to one of the dual reverberatory furnaces at a feed ratio of 17%.

Demolition Waste

The demolition waste consisted mainly of wood coated with lead based paint and had a lead concentration of between 0.5% and 1% The test material was shredded in a pallet shredder before it was smelted. The demolition debris was processed through both reverberatory furnaces at feed ratio of 10% test material, by weight. At this weight ratio the test material comprised 50% of the volume fed to the furnaces. This high volumetric ratio caused malfunctions in the furnaces, so the feed ratio was reduced to 5%, at which point the material was successfully fed.

NL Industries Superfund Site

The NL Industries site in Pedricktown, NJ, was an integrated battery breaking, smelting, and refining facility with its own onsite landfill. There was a wide variety of materials at the site including lead slag, dross, debris, ingots, hard heads (large chunks of metallic lead), battery case debris, baghouse bags, and contaminated pallets and iron cans. The evaluation was conducted in two parts: a preliminary investigation and a full-scale investigation.

During the preliminary investigation, approximately 370 tons of all types of the above materials were processed. Analyses revealed an average lead concentration of 57%; however, the materials ranged in concentration from 7% to 69% lead. The larger pieces of debris were removed and processed through a blast furnace; while the bulk of the material was fed into a reverberatory furnace at feed ratios of up to 100%. The feed was sufficiently dense to cause breakdowns in the reverberatory furnace conveyor feed system, so the feed ratio was reduced to 50% test material, by weight.

During the full scale operation, approximately 1200 tons of material were transported to the smelter over a three month period. During the first two months the test material, which contained approximately 45% by weight lead, was processed in the reverberatory furnace, at a feed ratio of 20% to 30%. The ratio was limited because of high amounts of calcium in the material. The high calcium concentration slowed the operation of the furnaces. During the last month of the evaluation, the test material consisted mainly of larger pieces of slag and debris with an average lead concentration of 30%. This material was charged to one of the blast furnaces at a feed ratio of approximately 30%.

Pennsylvania Department of Transportation

The Pennsylvania Department of Transportation (PennDOT) used an iron-shot abrasive blasting material to remove lead-based paint from a bridge in Belle Vernon, PA. Sixteen 55-gal steel drums of this material, containing an average of 3.2% lead, were processed at the smelter. The material contained too much moisture to be incorporated into the reverberatory feed. The test material, including the drum, was charged directly to a blast furnace at a feed ratio of approximately 13%, by weight. The bridge blasting material was primarily iron (60%) with 5% calcium and 5% to 10% misture content.

Test Procedures

Test material was charged to either the reverberatory furnaces or blast furnaces, depending primarily on the size of the material, but also on other factors such as lead content and percent ash. Project personnel collected samples and data to assess the furnace performance, characterize the input material, and characterize the furnace outputs. Table 2 shows the parameters that were measured and how they were obtained. The input material parameters were characterized to provide information related to the feed, so that comparisons of the effects of different feeds could be made. The furnace performance parameters, such as oxygen usage, fuel usage, furnace feed rates, etc., provided important furnace operation information while the experiments were conducted, principally indicating when production levels were falling or materials were clogging in the furnace. The output parameters were the most important measurements of furnace performance, including production rates and quality, as well as residuals generation.

The data generated from measurements and sample analyses were used to compare the performances of the test and control furnaces. The amount of lead in each product is useful in making a mass balance for the lead. Other parameters, such as oxygen, air, and fuel, are useful in determining the cost for processing the test material.

Table 2. *Input, Output, and Operating Parameters*

Input Material Characterization	*Furnace Performance Parameters*	*Furnace Output Parameters*
*total lead (S)**	*test material in the feed (M)**	*lead production rates (M)*
sulfur (S)	*air flow (M)*	*slag production rates (M)*
silica (S)	*% oxygen enrichment (M)*	*slag viscosity (O)**
calcium (S)	*fuel usage (M)*	*% lead in the slag (S)*
moisture content (S)	*lead inputs (S)*	*% sulfur in the slag (S)*
density (M)	*iron inputs (S)*	*back pressure (M)*
particle size distribution (M)	*% test material in feed (M)*	*sulfur dioxide emissions (M)*
BTU value (S)		*calcium sulfate sludge (S)*

**(S)=Sample (M)=Measurement (O)=Operator Observation*

Results

In general, the study demonstrated that various materials may be processed in secondary lead smelters with relatively few effects on overall furnace performance. The most significant effects were caused by processing materials in a furnace without properly preprocessing it or by processing too much material at one time. For example, the Tonolli feed was too large to be processed effectively in the dual reverberatory furnaces. This caused the furnace production to slow down significantly. Later, the same type of material from the Hebelka site was successfully processed in the reverberatory furnaces after it had been shredded in a hammermill to a particle size of less than 1/4-in. The NL Industries site material was initially unsuccessfully processed at a 100% feed ratio because it was too dense for the feed system. When the ratio of test material to total feed was lowered to 50% the material was processed with few problems.

Feed Ratios

The normal feed-to-waste ratio for these materials was one of the parameters tested during this study. Based on furnace performance and operations results, it was possible to determine whether the furnace performed successfully or unsuccessfully at any given feed ratio. A test is considered to be unsuccessful if the feed ratio of test material has to be lowered, or discontinued altogether.

Test results show that the successful mix ratios are strongly a function of the percentage of lead in the waste material. Figure 2 shows the successful feed ratios, plotted against the percentage of lead in the waste material (i.e., before blending with normal feed). The results are nearly linear from streams containing 3% lead to those containing 60% lead. This delineates the region marked "successful" on the figure. When the feed ratios versus lead concentration for unsuccessful runs are plotted, a second region (the "unsuccessful" area) emerges. Finally, a third region, in which no tests were performed, is also marked on the figure. No test feed with more than 60% lead was fed to the furnaces, so the regions in the range above 60% lead cannot be determined from the experimental results.

Reclamation Efficiency

In determining whether the process is suitable for reclamation of lead, it is important to determine whether the smelter actually reclaimed the lead in the test material. Unfortunately, there is no way to accurately measure the extent of reclamation because the test material has to be mixed with typical feed. Based on conservative assumptions and furnace output parameters such as initial lead content and percent ash, CHMR developed a method to estimate the minimum reclamation efficiency. This method indicated that lead was reclaimed from all test materials over a range of efficiencies, from an estimated 70% for the abrasive blasting material to 99.5% for NL Industries material.

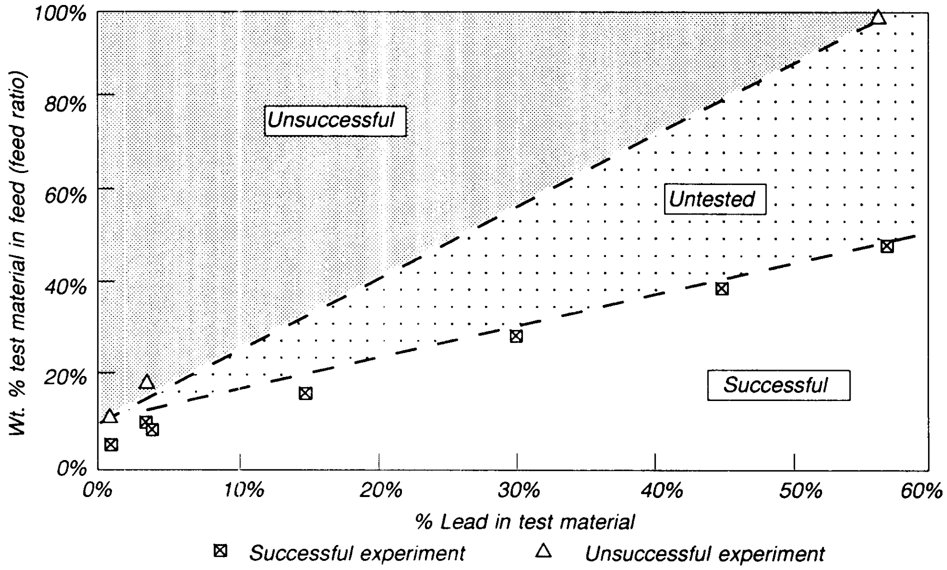

Figure 2. *Percent lead in test material versus feed ratio.*

Economics

CHMR used the experimental data and other information to develop an economic model based on the following costs and values of recovered materials:

- Excavation costs
- Transportation costs
- Smelter processing base cost
- Additional production costs associated with storage and handling of an atypical material at the smelter
- Additional disposal costs
- Lead recovery
- Reduction of iron, coke, or other furnace feeds.

With this model, the costs in the following table have been estimated for the materials used in this evaluation. Table 3 includes two costs, the first is based on a conservative market value for lead ($650/ton) and the second on a more plausible long-term value for lead ($750/ton). Note the relationship between the costs and some of the material characteristics. Lower lead content causes an increase in costs, whereas ash content and distance from the smelter have a lesser effect.

Conclusions

The conclusions drawn from the study are:

- Lead was successfully reclaimed from a variety of materials found at many Superfund sites, including battery case pieces, slag, dross, lead debris, spent abrasive material, and demolition material contaminated with lead paint. The lead concentration in these materials ranged from 1% to 45%
- The economics of reclaiming lead depend on lead concentration, market price for lead, distance from the smelter, percent of test material that becomes incorporated into the final slag, iron content, BTU value of the test material, and sulfur content.
- The cost for recovering lead from the five sites selected for this project, based on a conservative market price for lead ($650/ton), ranged between $80 and $374/ton.

Overall, CHMR concludes that secondary lead smelters provide a viable alternative to stabilization and disposal for the treatment of wastes found at battery breaker and some Superfund sites. This process also makes it possible to recycle and reuse lead which is a useful resource.

Table 3. *Estimated Cost of Remediating Sites*

Site	*P=$650/ton*	*P=$750/ton*	*Distance(miles)*	*% Ash*	*% Lead*
Tonolli	*$228*	*$224*	*40*	*20*	*3.5*
Hebelka	*174*	*160*	*75*	*30*	*14.7*
Demolition Material	*374*	*373*	*100*	*4*	*1.0*
NL Industries	*80*	*35*	*300*	*65*	*45.0*
PennDOT	*231*	*228*	*250*	*70*	*3.2*

Stephen W. Paff and Brian E. Bosilovich are with the Center for Hazardous Materials Research.
***Laurel Staley** is the EPA Project Officer (see below).*

The complete report, entitled "Emerging Technology Report: Reclamation of Lead from Superfund Waste Material Using Secondary Lead Smelters," (Order No. PB95-199022; Cost: $19.50, subject to change) will be available only from:

National Technical Information Service
5285 Port Royal Road
Springfield, VA 22161
Telephone: 703-487-4650

The EPA Project Officer can be contacted at:

Risk Reduction Engineering Laboratory
U.S. Environmental Protection Agency
Cincinnati, OH 45268

United States
Environmental Protection Agency
Center for Environmental Research Information
Cincinnati, OH 45268