United States
Environmental Protection
Agency

EPA/540/SR-94/513
August 1994

EPA

SITE

SUPERFUND INNOVATIVE
TECHNOLOGY EVALUATION

Emerging Technology Summary

Acid Extraction Treatment System for Treatment of Metal Contaminated Soils

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The Acid Extraction Treatment System (AETS) is intended to reduce the concentrations and/or leachability of heavy metals in contaminated soils so the soil can be returned to the site from which it originated. The objective of the project was to determine the effectiveness and commercial viability of the process. The report summarized here is an account of the activities conducted during the project, the experiments performed, results and conclusions.

A pilot-scale AETS system was used to treat 5 different soils containing different combinations of seven heavy metals. The study showed that AETS is capable of treating a wide range of soils, and reducing the TCLP metals to below the RCRA limits. The AETS can, in most cases, treat the entire soil, with no separate disposal or stabilization of the clay fines needed. The estimated treatment costs are between \$80 and \$240/yd^3.

This project summary was developed by EPA's Risk Reduction Engineering Laboratory, Cincinnati, OH, to announce key findings of the research project that is fully documented in a separate report of the same title (see Project Report ordering information at back).

Introduction

Through a Cooperative Agreement with the U.S. Environmental Protection Agency's (USEPA) Risk Reduction Engineering Laboratory (RREL), the Center for Hazardous Materials Research (CHMR) developed the Acid Extraction Treatment System (AETS). The project was conducted with support from Interbeton bv and The Netherlands Organization for Applied Scientific Research (TNO), located in the Netherlands. AETS is intended to reduce the concentrations and/or leachability of heavy metals in contaminated soils to render the soils suitable to be returned to the site from which they originated. Additional applications may include treatment of contaminated sediments, sludge and other heavy metal-containing solids.

The objective of the project was to determine the effectiveness and commercial viability of the AETS process in reducing the concentrations and leachability of heavy metals in soils to acceptable levels. This report represents an account of the activities conducted during the project, the experiments performed, and the results.

A pilot scale system was designed, constructed, and used to test different soils. Five soils were tested, including EPA Synthetic Soil Matrix (SSM), and soils from

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four Superfund sites (NL Industries in Pedricktown, NJ; King of Prussia site in Winslow Township, NJ; smelter site in Butte, Montana; and Palmerton Zinc site in Palmerton, PA). These soils contained elevated concentrations of arsenic, cadmium, chromium, copper, lead, nickel, and zinc.

Process Description

A simplified block flow diagram of the AETS process is shown in Figure 1. Full-scale units are anticipated to be able to process between 10 and 30 tons/hr. The first step in the full-scale AETS process is screening to remove coarse solids. These solids, typically greater than 4 mm in size, are anticipated to be relatively clean, requiring at most a simple rinse with water or detergent to remove smaller attached particles. If the soil contains a high percentage of clays, these may be removed as well for treatment separately.

After coarse particle removal, the remaining soil is scrubbed in an attrition scrubber to physically remove the metals and break up agglomerations. Then it is contacted with acid (HCl) in the extraction unit.

The residence time in the unit may vary depending on the soil type, contaminants and contaminant concentrations, but is anticipated to range between 10 and 40 min. The soil/extractant mixture is continuously pumped out of the mixing tank, and the soil and extractant are separated using hydrocyclones. The solids are piped to the rinse system, while the cyclone overflow (extractant) are treated using a proprietary technology which removes the metals and regenerates the acid.

The soils are rinsed with water to remove entrained acid and metals. The metals are removed from the rinsate using the same technology that regenerates the acid. After rinsing, the soil is dewatered using hydrocyclones and (if required) dewatering screens. In the final step, the soils are mixed with lime and fertilizer to neutralize any residual acid and return the soil to natural conditions.

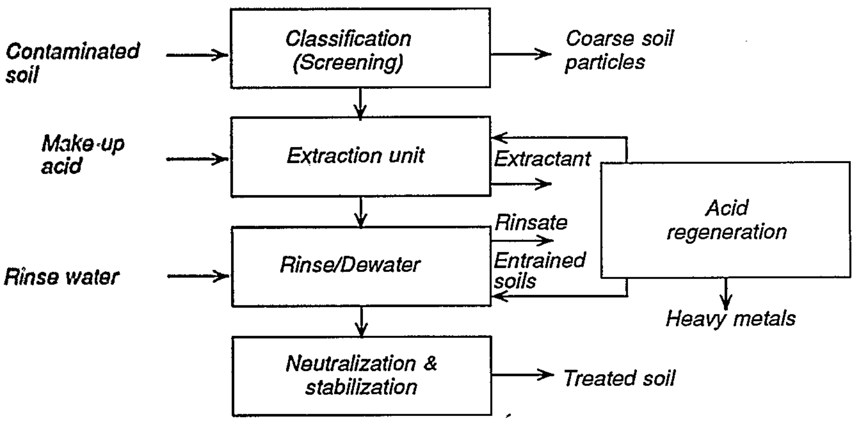

Figure 1. AETS block flow diagram.

Test Procedures

This section describes the experimental procedures used with the pilot-scale AETS unit, which is capable of processing between 20 and 100 kg of soil per hour.

The soils were initially characterized for total and TCLP metals content. The soils were screened to remove the +8 mesh fraction on a mechanical shaker prior to being placed in the lab-scale attrition scrubber, where the soil was slurried with water or regenerated hydrochloric acid from previous experiments.

Next, the soil was contacted with hydrochloric acid for residence times between 10 and 40 min. in the extraction tank. The pH of the mixture was maintained between 1.8 and 2.2. Figure 2 shows the flow diagram for the extraction step. During extraction, the solids were separated using two hydrocyclones, and returned to the extraction tank. The extractant was pumped to the acid regeneration system, and then returned to the extraction tank.

At the end of the experiment, the soil was dewatered using two cyclones and a mechanical shaker with a 200 mesh screen to separate the solids and the extractant. The extractant was then regenerated to be used as the acid in the next experiment, and the solids were prepared for the rinsing step.

The solids were rinsed in water to remove any residual acid. The metals were removed from the rinse water using a separate regeneration system than the one used during the extraction. The clean solids and all liquids were then analyzed for total and TCLP metals to form a material balance. The rinse water was ready for the next experiment, so no waste streams were generated.

Experimental Soils

This section gives a brief discussion of the five soils used during the laboratory- and pilot-scale investigations.

Synthetic Soil Matrix

The Synthetic Soil Matrix (SSM) is produced by EPA specifically for use in research and development of emerging or innovative technologies. The soil is a mixture of clay, silt, sand, gravel, and topsoil that is blended together to form the soil matrix. Organic and inorganic contaminants are added based on typical hazardous materials at Superfund sites. Table 1 lists the total and TCLP metals concentrations in the initial SSM.

NL Industries Site

The NL Industries site, located in Pedricktown, NJ, was an integrated battery breaking and lead smelting facility. The soil is contaminated with copper, lead, and zinc, but was chosen for this project due to the high levels of lead. The total lead concentrations ranged from 23,200 to 29,200 mg/kg and TCLP concentrations ranged from 500 to 520 mg/L.

King of Prussia Site

This site, in Winslow Township, NJ, was used to neutralize acid streams from an adjacent site. The soil is contaminated with chromium, copper, and nickel, and it is not hazardous by RCRA standards. The site was placed on the National Priorities List (NPL) because of high levels of chro-

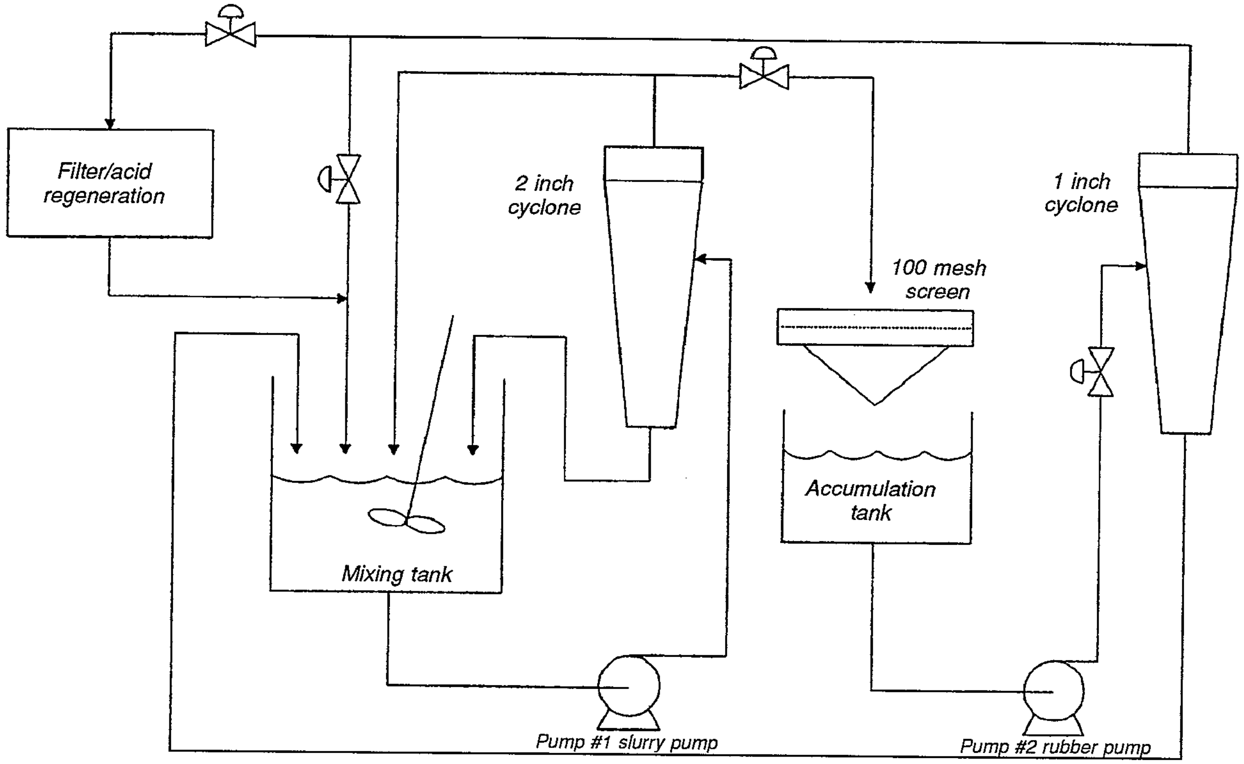

Figure 2. *Extraction flow diagram.*

Table 1. *Synthetic Soil Matrix Contaminant Levels*

Metal	Total Range (mg/kg)	TCLP Range (mg/L)
As	620 to 730	4.0 to 4.2
Cd	970 to 1,130	41.0 to 48.9
Cr	1,320 to 1,640	<0.05
Cu	10,900 to 12,400	297 to 298
Pb	10,040 to 10,800	26.0 to 27.1
Ni	980 to 1,410	35.6 to 35.9
Zn	20,500 to 26,300	669 to 719

Table 2. *King of Prussia Contaminant Levels*

Metal	Total Range (mg/kg)	TCLP (mg/L)
Cr	1,020 to 1,390	0.20
Cu	1,240 to 2,030	7.10
Ni	335 to 518	27.6

mium. Table 2 describes the extent of contamination in the initial soil.

Silver Bow Creek Site

This site, in Butte, MT, contains a very sandy soil, with very little clay. The soil is contaminated with copper and zinc, with total metals ranging from 98 to 127 mg/kg, and 1,170 to 1,350 mg/kg, respectively. The TCLP range was from 1.4 to 1.7 mg/L for copper, and 2.6 to 7.1 mg/L for zinc. The Butte soil was non-hazardous soil, but still contained metals that needed removal.

Palmerton Zinc Site

This site, located in Palmerton, PA, was an old zinc smelting facility. Only one experimental extraction was conducted on this material, due to a lack of the soil. This soil was chosen due to its high levels of zinc, but also because it contained lead, cadmium, and copper. Table 3 summarizes the concentrations of the metals in the initial soil.

Results

Table 4 and Table 5 summarize the results of tests using the five different

Table 3. Palmerton Soil Contaminant Levels

Metal	*Total Metals (mg/kg)*	*TCLP Metals (mg/L)*
Cd	*137*	*2.60*
Cu	*166*	*0.16*
Pb	*898*	*0.66*
Zn	*9,150*	*71.0*

soils, containing seven separate metals. The results indicate that the AETS process can reduce the concentrations of heavy metals and reduce the TCLP leachability levels to below current regulatory limits.

Table 4 summarizes the soil treatability across the soils and metals tested. Where individual soil fractions were separated during the extraction, and analyzed separately, the table shows the composite results if the entire soil had been remixed. The results show that AETS treated virtually all the soils tested to both reduce the total metals concentrations to below currently regulated concentrations and reduce the TCLP to below the currently regulated concentrations. The only exceptions were cadmium, which consistently failed the TCLP for SSM soil, and lead, which failed both the TCLP and total metals requirements for SSM soils.

Table 5 shows the results obtained from the lead contaminated soil from the NL Industries Superfund site in Pedricktown, NJ. The table shows over 90% reductions in total metals concentrations, and a 99% reduction in TCLP. Further work indicated that the TCLP and total lead in the soil could be reduced to below 5 mg/L and 1000 mg/kg, respectively.

The experimental work was completed during January 1993, and the final report has recently been issued.

Process Economics

Table 6 below shows the cost summary for AETS at several different process configurations. The table shows the effects of varying six critical parameters (feed rate, extraction time, percent fines, metals concentrations, site size and the number of sites treated with each set of equipment).

Note that the table includes costs for mobilization, pilot plants, excavation, replacing soil, and reseeding the ground as well as soil treatment. Thus, the costs represent the *total costs* of treatment using the Acid Extraction Treatment System. Also note that the table conservatively assumes that the capital costs of the AETS system are amortized over only 1 or 2 sites, and that the plants operate only one 8 hour shift per day. Finally, the economic calculation assumes that the metal sludge is stabilized and disposed, and not reclaimed. The metals in many sites may be reclaimable. Relaxing all of these conservative assumptions will reduce the estimated treatment costs by 20 to 30%.

Conclusions

The results of the study are summarized below:

- AETS is capable of treating a wide range of soils, containing a wide range of heavy metals to *reduce the TCLP below the RCRA limit and to reduce the total metals concentrations below the California-mandated total metals limitations.*
- In most cases, AETS is capable of treating the *entire* soil, with no separate stabilization and disposal for fines or clay particles, to the required TCLP and total limits. The only exception to this among the soils tested was with the SSM, which may require separate stabilization and disposal of 20% of the soil because of lead. This soil was successfully treated for other metals, including arsenic, chromium, copper, nickel and zinc.
- Costs for treatment, under conservative process conditions, range between $80 and $240/yd³ of soil, depending on the site size, soil types and contaminant concentrations.

Table 4. Qualitative Results of Extractions

	Soil				
Metal	*SSM*	*Butte*	*King of Prussia*	*Pedricktown*	*Palmerton*
As	*, T, L	*, T, L			
Cd	*, T				*, T, L
Cr	*, T, L		***, T, L**	*, T, L	
Cu	***, T, L**	*, T, L	*, T, L		*, T, L
Ni	*, T, L		*, T, L		
Pb	*	*, T, L		***, T, L**	*, T, L
Zn	***, T, L**	*, T, L		*, T, L	*, T, L

** - Metal is present in the soil*
T - Successful treatment for total metals
L - Reduction in leachability to below standards
Bold and large fonts indicate high initial metals content (at least double regulatory standards)

Table 5. *NL Industries Soil*

Total Metals (mg/kg)			
Metal	Initial	Final	% Removal
Pb	29,200	1,310	95.5%

TCLP (mg/L)			
Metal	Initial	Final	% Removal
Pb	520	5.1	99.0%

Table 6. *AETS Cost Summaries Under Various Conditions*

Process and Site Parameters					*Amortized Capital and Operating Costs ($/m³)*
Feed Rate (yd³/hr)	*Extraction Residence Time (min)*	*% Fines (<50μm)*	*Metals Conc. (mg/kg)*	*Site Size (1000 yd³)*	
30	*24*	*15*	*5,000*	*150*	*77*
20	*24*	*15*	*5,000*	*100*	*96*
20	*36*	*30*	*15,000*	*60*	*138*
20	*24*	*15*	*15,000*	*80*	*118*
15	*24*	*15*	*5,000*	*60*	*122*
15	*36*	*30*	*15,000*	*30*	*193*
15	*36*	*15*	*5,000*	*30*	*168*
10	*36*	*30*	*15,000*	*20*	*241*

The following notes apply to this table:
1. *Plant is operating for only 1 eight hour shift per day.*
2. *No metal recovery value is assumed. All metal sludge is disposed.*

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***Naomi P. Barkley** is the EPA Project Officer (see below).*
The complete report, entitled "SITE Emerging Technologies: Acid Extraction Treatment System for Treatment of Metal Contaminated Soils," (Order No. PB94-188109/AS; Cost: $19.50, subject to change) will be available only from:

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