Cement-Based Solidification/Stabilization of Lead-Contaminated Soil at a Utah Highway Construction Site

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This article describes portland cement-based solidification/stabilization (S/S) treatment of heavy metal-contaminated soil. The soil was discovered during highway construction in West Jordan, Utah. Environmental Chemical Corporation (ECC) performed an emergency response to remediate the soil under contract with the EPA and the United States Bureau of Reclamation (USBR). The soil was treated by S/S. Treatment of the soil, contaminated with lead and arsenic, involved: (1) excavation, (2) size segregation, (3) reduction of oversized particles, (4) addition and mixture of portland cement and cement kiln dust, and (5) beneficial reuse of the treated soil as a subbase. S/S treatment successfully reduced Toxicity Characteristic Leaching Procedure (TCLP) concentrations of the contaminants to below regulatory levels.

During highway construction in West Jordan, Utah, the Utah Department of Transportation (UDOT) discovered lead/acid battery waste in the soil of the road right-of-way and adjacent property. Approximately 1,900 cubic meters (2,500 cubic yards) of soil was contaminated with lead/acid battery remains, lead ingots, metal, concrete, and plastic debris. Laboratory analysis of this soil indicated concentrations of lead in the soil of up to 200,000 ppm and elevated arsenic concentrations.

Under authorities granted by the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA), commonly known as Superfund, the Emergency Response Branch of EPA Region 8 conducted an emergency response to the site. The EPA selected solidification/stabilization (S/S) treatment as the remedy for the site.

Soil contaminated with lead was successfully treated by portland cement-based S/S. S/S treatment was demonstrated as a cost-effective response alternative. Contaminated materials were safely treated and then reused as a subbase for pavement at a landfill.

WHAT IS S/S?

EPA characterizes S/S as an established treatment technology and has selected S/S treatment of more than 25 percent of its Superfund remedial

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program site remedies. S/S treatment involves mixing a binding reagent with contaminated soil, sediment, or sludge to physically and often chemically immobilize hazardous constituents within the treated waste. Because it is an effective, readily available, and consistent manufactured product, portland cement has been used as a binding reagent for a greater variety of wastes than any other reagent.

90TH SOUTH BATTERY SITE PROJECT

On the behalf of EPA, the United States Bureau of Reclamation (USBR) contracted Environmental Chemical Corporation (ECC) to perform the emergency response. The EPA maintains a list of remedial contractors that are prequalified to perform Fixation/Stabilization Systems, also known as S/S. This list is part of the EPA's Pre-Qualified Offerors Procurement Strategy (PQOPS). By maintaining a list of prequalified contractors, EPA streamlines its contractor procurement procedure. This allows EPA to respond quickly on emergency responses. ECC was selected from this list.

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S/S treatment of the soil included: (1) excavation, (2) size segregation, (3) reduction of oversized particles, (4) addition of portland cement and cement kiln dust as binding reagents (5) mixture of the contaminated soil and debris with the binding reagents, and (6) beneficial reuse of the treated soil as a subbase.

The site is located at the intersection of the Bingham Creek Channel, the existing 90th South Street and the planned West Valley Highway crossing in West Jordan, Utah. This is a residential area in front of the Holy Cross Jordan Valley Hospital. UDOT discovered broken battery casings and particles of lead during the course of highway construction operations. On May 27, 1994, UDOT estimated that there were 40 cubic meters (50 cubic yards) of battery waste contaminated soil and debris. By June 6, 1994, UDOT increased its estimate to about 850 cubic meters (1,100 cubic yards). The contaminated area was about 18 meters (20 yards) by 30 meters (33 yards) by 1.5 meters (1.6 yards) in depth.

UDOT sampling results of the soil indicated lead levels as high as 210,000 mg/kg, with a corresponding Toxicity Characteristic Leaching Procedure (TCLP) level of 90 mg/l. Sampling from various places of the contaminated area indicated similar results. Sampling also revealed significant elevated arsenic levels in the soil.

In order to continue its highway construction, UDOT excavated the contaminated soil from the right-of-way. Eventually, UDOT excavated 1,260 cubic meters (1,650 cubic yards) of contaminated soil and debris and stockpiled it on a 30-mil plastic liner on the southeast side of the proposed highway.

SITE REMEDIATION

The emergency response at the 90th South Battery Site included the following operations: environmental assessment, soil excavation, treatability studies, size screening of soil and debris, crushing of oversized material, S/S with portland cement and cement kiln dust, analytical testing, and transportation and disposal. A total of 1,900 cubic meters (2,500 cubic

Exhibit 1. Alternatives Reviewed.

Alternative	Cost Effectiveness	Efficiency	Risk Reduction	Other
No action	None	None	None	
Recycling of metallic waste				No Smelter Available
Precious metals extraction	Low	Low	Low	
Hand sorting of debris followed by S/S	Low	Low	Moderate	
Magnetic separation followed by S/S	Low	Moderate	High	
Size reduction, density separation followed by S/S	Low	Low	Moderate	Space restrictions
Off-site stabilization and landfilling	Very Low	High	High	
Encapsulation in on-site burial vaults	Very Low	Very Low	Moderate	
Incineration	Very Low	Moderate		High
On-site crushing and S/S followed by off-site disposal	High	High	High	

yards) of contaminated material, with lead and arsenic as primary contaminants of concern, was S/S treated on-site.

ENVIRONMENTAL ASSESSMENT

The elevated levels of lead and arsenic in the UDOT-stockpiled material indicated that the waste could not be safely left untreated. Lead battery contaminated soil and debris were also found on property adjacent to the UDOT right-of-way. Soil on property owned by the U.S. Department of the Interior (DOI) and beneath and along side of an entrance road to Holy Cross Jordan Valley Hospital was sampled and found to be contaminated.

The sampling was conducted by EPA Region 8's Technical Assistance Team (TAT) contractor-Ecology and Environment. These samples were analyzed using X-ray fluorescence spectrometry (XRF) at laboratories from the Midvale and Sandy Smelters Superfund sites.

REVIEW OF ALTERNATIVES

ECC under contract with the EPA reviewed alternatives for management of the contaminated material. The alternatives reviewed and qualitative assessments of each alternative's cost effectiveness, efficiency of response action time, risk reduction, and other considerations are summarized in **Exhibit 1**.

The relative merits of each alternative were reviewed. Based on this review, on-site crushing of the contaminated material followed by S/S treatment and off-site disposal was selected as the emergency response.

SOIL EXCAVATION

A chain-link fence was installed on the north side of 90th South, enclosing 21,000 square meters (25,000 square yards) of property adjacent to the UDOT right-of-way. This adjacent property was owned by DOI and the hospital. All of the contaminated material stockpiled earlier by the UDOT were transferred to this location. In addition to the UDOT stockpile, ECC excavated about 650 cubic meters (850 cubic yards) of contaminated soil and debris from the adjacent property using a back hoe, placing it within the fenced area. ECC excavated soil with lead contamination above 1,000 ppm beneath the surface and 500 ppm at the surface. These excavated areas were back filled by the State of Utah with noncontaminated back-fill material.

SIZE SEPARATION

The 1,900 cubic meters of contaminated material included soil, rock, plastic battery casings, and smelter slag ingots of various sizes up to 4,600 mm (18 in). For effective S/S treatment, all particles of the material had to be graded to less than 32 mm (1.25 in) in size. To meet this requirement, the excavated material needed to be segregated into two different stockpiles—greater than 32 mm in size, destined for further crushing, and less than 32 mm in size. To accomplish this segregation, all the material was processed through a machine known as a "grizzly." The inlet grate to the grizzly had 130-mm (5-in) square openings.

Debris greater than 130 mm was separated on entry, and material that passed the grate was screened by a 32-mm screen. The segregation process resulted in two piles. One pile consisted of 1,200 cubic meters (1,600 cubic yards) of particles less than 32 mm. This pile consisted primarily of soil, plastic battery parts, rock, and some smelter slag ingots. The other pile consisted of 700 cubic meters (900 cubic yards) greater than 32-mm particles consisting primarily of debris, plastic battery casings, 32-4600-mm smelter slag ingots, concrete slabs, asphalt, river rock, and some heavy equipment parts.

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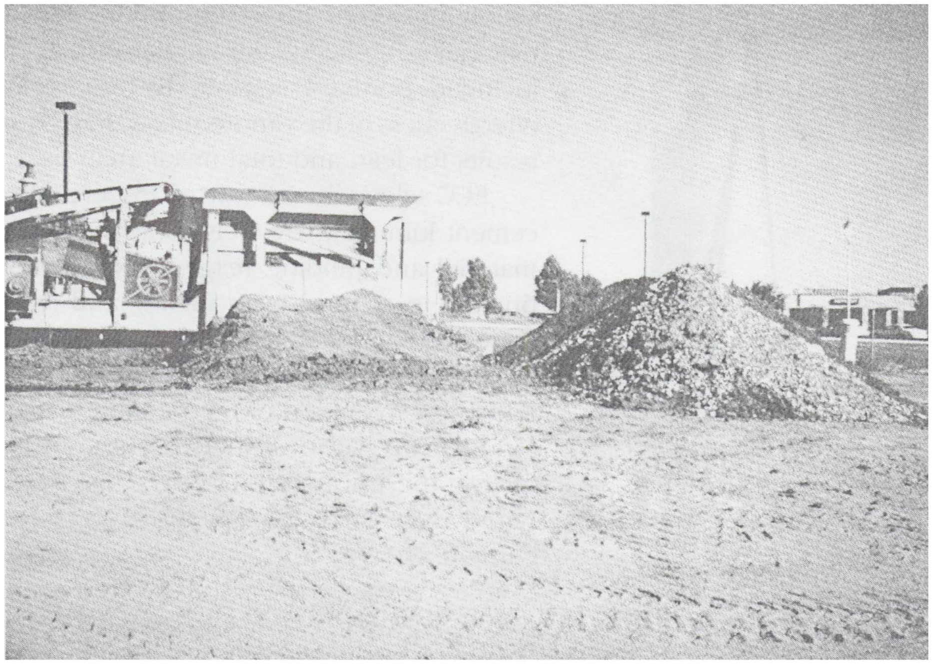
SIZE REDUCTION

After the segregation, the oversized (greater than 32 mm) material was passed through a closed circuit horizontal impact crusher. A 150 RDS impact crusher with a bearclaw impact was selected based on its availability, effectiveness, production rate, and cost. The impact crusher was rated at 45 tonnes (50 tons) per hour for crushing material to less than 6.5 mm (0.25 in).

During initial operations, ECC discovered that sieving material on the originally selected 6.5-mm sieve posed several problems. Crushing to a small particle size created a dusting problem. Water used for dust suppression caused clay in the material to ball-up thus plugging of the recycling screens in the crusher. This caused the material within the impactor to recycle back into the impactor, further reducing production efficiency. Plugging caused time delays since production often needed to be halted in order to clean the screens. Since smelter slag ingots were part

Exhibit 2. Oversized Material Awaiting Processing.



Photograph by Rich Warren, Holnam, Inc., Salt Lake City, Utah.

of the greater than 32-mm faction, and size reduction was needed in order to effectively treat the material, the remediation contractor was faced with a dilemma.

ECC found that the smelting slag ingots were very brittle. The impact crusher was capable of crushing them to less than 4 microns in the first pass. This implied that increasing the recycling screen size to 32 mm would still result in sizes small enough for effective treatment, thus solving the problem. The recycling screen was changed to 32 mm. The large screen size resulted in larger particle sizes, reducing the amount of dust produced. This, in turn, resulted in less water being used for dust suppression. Fewer process interruptions were needed to clean the clogged screens. The crushing operation, including setup time, downtime, and run time, lasted for three weeks. **Exhibit 2** shows the oversized material awaiting processing by the impact crusher.

The crushed material was combined with the pile of less than 32-mm material using a front-end loader. At the same time, limestone fines were added to the material to adjust the pH. The pH of the soil ranged from 5 to 7. The low (5) pH of some portions of the soil was possibly the result of contamination by battery acid. About 5 percent (by weight) of limestone fines were added. The pH of the "buffered" soil ranged from 7 to 8. Dust suppression with water was employed during processing and transportation operations.

MIXING WITH PORTLAND CEMENT AND CEMENT KILN DUST

Treatability studies were conducted early in the response to select an effective bind reagent mixture and addition rate. Preweighted composite soil samples were mixed thoroughly with different amounts of pozzolanic material in 4.4-liter (1 gallon) plastic bags. The pozzolanic materials tested included portland cement, fly ash, cement kiln dust, and lime. The effectiveness of the various mix designs was evaluated on the basis of TCLP results for lead and total metal analysis.

ECC selected a mixture of 75-percent portland cement and 25-percent cement kiln dust (by weight) as the binding reagent. The contaminated material and binding reagent were combined using a Protec 55-series pugmill to achieve even mixing and reaction. The binding reagent was added to the contaminated material in amounts ranging from 15 percent to 17 percent (by weight). About 10 percent (by weight) of water was added for hydration of the binding reagent.

Exhibit 3 shows the mixing equipment setup on site. From right to left, the photograph shows: (1) the input hopper where contaminated material is introduced using a front-end loader, (2) portland cement/cement kiln dust silo and metering system that places the binding reagent on top of the contaminated material moving past on a conveyer belt, (3) pug mill where the reagent and material are mixed with an addition of water, and (4) conveyer belt removing treated waste from the pug mill and discharging into a pile. The physical consistency of the treated material resembled crumbly earth. **Exhibit 4** shows the consistency of the treated soil.

The S/S treatment used a total of 280 tonnes (310 tons) of portland cement and 94 tonnes (104 tons) of cement kiln dust.

TREATMENT RESULTS

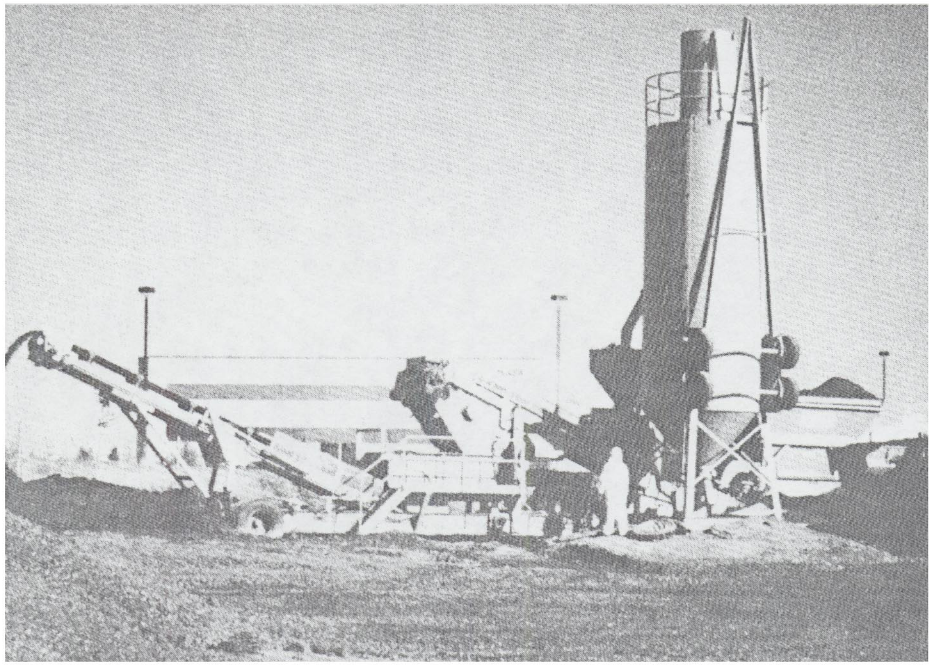
The effectiveness of the S/S treatment was determined by performing TCLP tests on the treated material.

The effectiveness of the S/S treatment was determined by performing TCLP tests on the treated material. A sample was collected from every 450 tonnes (500 tons) of treated material. Sampling was performed on the treated soil immediately after the treatment process. The TCLP leachates were analyzed for lead and arsenic. The regulatory limits for both lead and arsenic is 5.0 mg/l each. Analysis of the samples indicated that the lead concentrations in the TCLP leachates were less than 0.72 mg/l, and arsenic concentrations were below its detection limit of 0.21 mg/l. The analytical results are presented in **Exhibit 5**.

USE OF THE TREATED MATERIAL

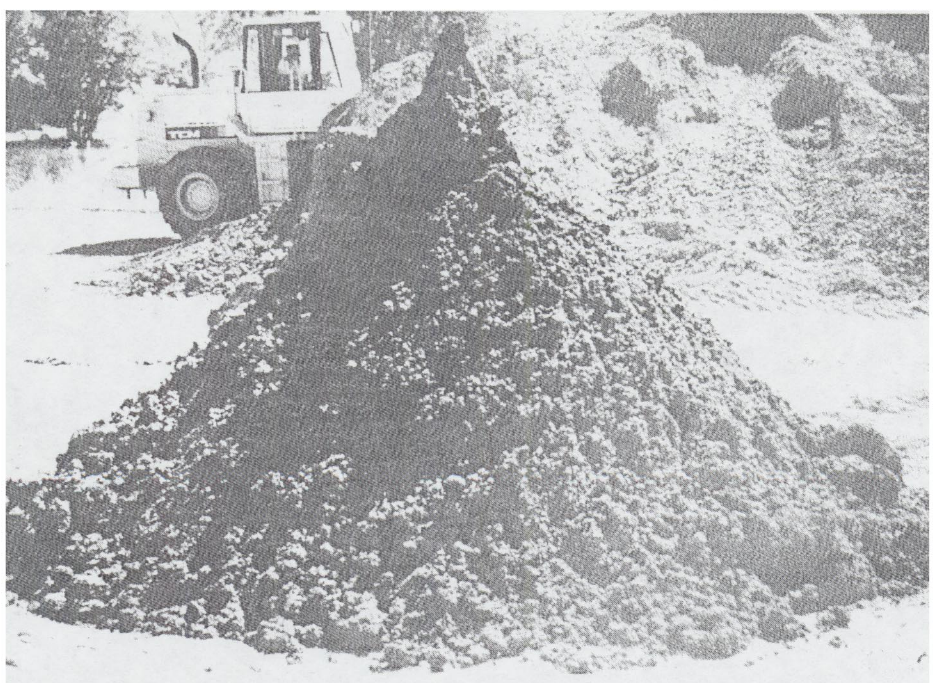
The treated material was transported to Salt Lake Valley, a municipal landfill. The landfill intends to use the treated material as a subbase for building a pavement for composting operations. The treated material was transported to the landfill in 11 cubic meter (14 cubic yards) end dump with a 7 cubic meter (9 cubic yards) dump trailer. The material was placed and compacted in a special cell that is 60 meters (70 yards) by 90 meters (100 yards). The material was spread in three 150 mm (6 in) lifts and compacted to 90 percent of maximum density.

Exhibit 3. The Mixing Equipment Setup.



Photograph by Rich Warren, Holnam, Inc., Salt Lake City, Utah.

Exhibit 4. The Consistency of the Treated Soil.



Photograph by Rich Warren, Holnam, Inc., Salt Lake City, Utah.

Exhibit 5. TCLP Results on Treated Material.

Sample Number	Arsenic in µ/l	Lead in µg/l
4923-092994-01	<210	145
4923-092294-02	<210	145
4923-093094-01	<210	293
4923-100494-01	<210	145
4923-100494-02	<210	676
4923-100494-03	<210	145
4923-100494-04	<210	145
4923-100494-05	<210	145
4923-100764-001 Dup.	<210	145
4923-100764-002 Dup	<210	145
4923-100764-003	<210	506
4923-100764-005	<210	145

CONCLUSION

Soil contaminated with waste from lead/acid battery debris was successfully treated by portland cement-based S/S. S/S treatment was demonstrated as a cost-effective response alternative. Contaminated materials were safely treated and then reused as a subbase for pavement at a landfill. ■

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