Selecting and Using Solidification/Stabilization Treatment

Solidification/Stabilization (S/S) is a widely used treatment technology to prevent migration and exposure of contaminants from a contaminated media (i.e. soil, sludge and/or sediments). According USEPA, S/S is among the most frequently used established (where cost and performance is often available) treatment technologies for on- and off-site remedies. S/S was used in 217 Superfund projects from 1982 to 2005.

- ***Solidification*** refers to a process that binds a contaminated media with a reagent changing its physical properties by increasing the compressive strength, decreasing its permeability and encapsulating the contaminants to form a solid material.

- ***Stabilization*** refers to the process that involves a chemical reaction that reduces the leachability of a waste, so it chemically immobilizes the waste and reduces its solubility; becoming less harmful or less mobile.

USEPA has also identified S/S treatment as Best Demonstrated Available Treatment Technology for at least 50 commonly produced Resource Conservation and Recovery Act (RCRA) hazardous wastes.

Effectiveness of Solidification/Stabilization on General Contaminant Groups for Soil and Sludge

S/S has been tested and evaluated for its effectiveness in containing and treating a wide array of contaminants, such as metals including lead, arsenic and chromium, and organic contaminants, such as creosote and petroleum products found at sites. S/S demonstrated effectiveness to following chemical groups:

- Halogenated Semivolatiles
- Non-halogenated Semivolatiles and Non- volatiles, such as PAHs, BTEX
- Non-volatile Metals
- Radioactive Materials
- Polychorinated Biphenyls
- Pesitcides
- Dioxins/Furans

For metals, S/S is most often selected for treatment of these contaminants because metals form insoluble compounds when combined with appropriate additives. According to the EPA S/S treatment was selected for source treatment of metals on 180 projects from 1982 to 2005.

One of the more optimal applications of S/S remediation is as a containment technology for remediation of contaminated industrial properties.

S/S also has been selected often and demonstrated excellent performance on MGP sites remediation.

Case Example 1: MGP Site Remediation - Kendall Square Redevelopment Project in Cambridge, Massachusetts

Kendall Square is a former MGP site that covered 10-acres in East Cambridge, Massachusetts. Byproducts from the MGP operations led to soil impacted with coal tar and petroleum residues. As a temporary cleanup remedy, a previous owner of the property capped the subsurface contamination with a parking lot, which remained in place for about 30 years. Revitalization of the area surrounding the property made it attractive for redevelopment. The results of an environmental investigation found 4 acres of soil impacted with polycyclic aromatic hydrocarbons (PAHs) and volatile organic compounds (VOCs), from 0 to 20 feet below grade; and a 3-acre non-aqueous phase liquid (NAPL) plume that consisted of: dense non-aqueous phase liquid (DNAPL) present at the groundwater/clay interface about 20 feet below grade and light non-aqueous phase liquid (LNAPL) on the groundwater surface about 10 feet below grade.

In-Situ Treatment Using Shallow Soil Mixing Method at Former MGP Site

Excavation and disposal was chosen as the remediation strategy for the parcels of the property outside the NAPL plume. In-situ S/S was selected to treat the NAPL plume and contaminated soil. A mixture of Portland cement, bentonite and water was mixed and injected into the impacted soil, immobilizing free-phase NAPL in the subsurface. In-situ soil mixing was accomplished using a 10-foot, crane-mounted auger system. The mixed soil columns were overlapped by 35 percent, ensuring that all impacted soil was treated (see Figure 3-3). S/S treatment resulted in immobilization of contaminants of concern within a 20-foot thick monolithic, solidified mass with a volume over 100,000 cy.

Case Example 2. South 8th Street Landfill Superfund Site in West Memphis, Arkansas

The South 8th Street Landfill was a 16.3 acre site located on the floodplain between the Mississippi River and the St. Francis Levee in West Memphis, Arkansas. The site was first used for waste disposal sometime after 1957. Between 1970 and 1980, a 2.6 acre pit at the site was used for disposal of waste oil sludge from a re- refining process. Between 1981 and 1988, EPA conducted investigations and found the site contaminated with PAHs, PCBs, benzene, toluene, ethyl benzene, and xylene (BTEX), pesticides, and metals. The principal threat was the waste pit, primarily due to the low pH of the wastes which were corrosive and could have caused severe burns.

The ROD specified ex-situ S/S treatment of the waste. Subsequent treatability testing by the PRP group demonstrated that the waste could be treated in-situ and was successful in meeting the following performance standards:

- *UCS > 50 pounds per square inch (psi)*
- *Hydraulic conductivity less $1x10^{-6}$ centimeters per second (cm/s)*
- *Leaching of lead < 15 micrograms per liter (µg/L) as determined by SPLP*

Augers were used to mix the reagent and sludge (see Figure 4-2). Approximately 40,000 cy of sludge were treated.

In-Situ Treatment of Sludge Pit Waste

Procedure for Apply S/S to a Specific Site

An important component of the S/S procedure is mixing of the unstabilized material and reagents. The ratio of reagents to unstabilized material to achieve target goals is typically determined by bench- scale treatability studies. The method that is selected may be inherent to a specific treatment method (e.g., in-situ drilling or ex-situ slurry mixing) and can be optimized during the bench-scale phase. In any method, mixing to achieve a homogenous condition is preferred.

Subsequent to bench-scale testing, a pilot-scale test may be performed to confirm the bench-scale results and to refine or revise the process as needed. The pilot-scale testing commonly includes the proposed full-scale equipment, or equipment that most closely simulates that proposed process.

Costs for in-situ treatment vary widely according to project size, subsurface soil characteristics, chemical nature of contaminants, and additives or reagents used and their availability.

Solidification/Stabilization Treatment Evaluation

Physical and chemical tests must be completed on contaminated material from the sites prior to implementation of S/S treatment.

- Leaching and extraction tests assist in determining the amount of hazardous contaminants that can leach from the treated waste under a worst- case scenario.
- Physical tests such as compressive strength can be used to determine absence of free liquids in treated material and also construction properties if treated material is intended for reuse or land disposal.
- Physical tests of solidified material are also used as indicators of the longevity of the solidification including resistance to freeze/thaw.

Typical S/S specifications are provided in Table 1. The commonly specified physical tests in project performance standards include hydraulic conductivity and unconfined compressive strength (UCS).

Table 1. Typical Solidification/Stabilization Specifications

Parameter	Units	Average Value (1)	Test Method
Unconfined Compressive Strength	Pounds per Square Inch	>50	ASTM D1633
Hydraulic Conductivity	Centimeters per Second	$<1x10^{-6}$	ASTM D5084
Leaching Tests	Milligrams per Liter	Site Specific	TCLP and SPLP
1 - Usually stated as “the average value of all treated must equal” (usually a 20% allowance is permitted for individual samples.			
TCLP - Toxicity Characteristic Leashing Procedure SPLP - Synthetic Precipitation Leashing Procedure			

The most commonly specified chemical test is the Toxicity Characteristic Leaching Procedure (TCLP). The TCLP is applied because it is linked to regulations in the EPA RCRA program. However, there has been discussion about the appropriateness of applying TCLP to S/S treated waste when this treated waste is managed other than in a municipal landfill. The TCLP procedure relies on extracting sample waste with a diluted organic acid, simulating conditions of mixed waste (including organic waste) disposal, such as in a municipal landfill. Many S/S-treated wastes are treated in situ and left in place. The TCLP procedure may not be the appropriate simulation of these disposal scenarios. To address this, the Synthetic Precipitation Leaching Procedure (SPLP) may be applied in place of the TCLP. The SPLP is designed to simulate waste exposure to acid rain. Decision makers should consider the final disposal environment of treated waste to determine the appropriate test.

Long-Term Permanence Evaluation

It is important that long-term monitoring be completed to insure that contaminants have not been re-mobilized.

Per USEPA, **Five-Year Reviews generally are required by CERCLA** or program policy **when hazardous substances remain on site above levels which permit unrestricted use and unlimited exposure**. Five-year reviews provide an opportunity to evaluate the implementation and performance of a remedy to determine whether it remains protective of human health and the environment. Generally, reviews are performed five years following the initiation of a CERCLA response action, and are repeated **every succeeding five years** so long as future uses remain restricted. Five-year reviews can be performed by EPA or the lead agency for a site, but EPA retains responsibility for determining the protectiveness of the remedy.

For long-term monitoring, the selected remedy to completed project should be to monitor groundwater and/or surface water downgradient of S/S treated source area.

Case Example 3: Recently a study was completed on the long-term effectiveness of S/S treatment on soils impacted by former MGP operations at a site in Columbus, Georgia. The study evaluated the structural integrity and geo-chemical nature of the treated soils 10 years after S/S treatment. The site was redeveloped into a park with a river walk along the Chattahoochee River.

In-situ S/S treatment of impacted soils at the MGP site was completed in June 1993. In 2003, cored samples of the treated soil were evaluated to identify chemical and physical deterioration. Results of the study concluded that after 10 years the S/S treated material solidified mass at the site continues to exceed original performance standards. The results of the 10-year study are summarized below:

- *Groundwater has not penetrated the solidified mass*
- *All samples surpassed geotechnical pre-remediation performance standards*
- *The liner integrity has remained in place*
- *Solid phase geochemistry did not show physical or chemical deterioration*
- *Groundwater monitoring has shown that leaching has not occurred*
- *Results from Remedial Options Assessment Modeling have shown there is low potential for leaching in future*