4.24 Solidification/Stabilization

(Ex Situ Soil Remediation Technology)

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Technology	Description
Soil, Sediment, and Sludge	
3.5 Ex Situ Physical/Chemical Treatment (assuming excavation)	
4.24 Solidification/ Stabilization (Ex Situ)	Contaminants are physically bound or enclosed within a stabilized mass (solidification), or chemical reactions are induced between the stabilizing agent and contaminants to reduce their mobility (stabilization).

Description:

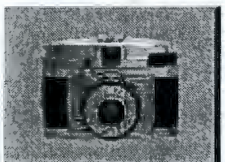

Figure 4-24: Typical Ex Situ Solidification/ stabilization Process Flow Diagram

As for in situ solidification/stabilization (S/S) (see Technology Profile No. 4.10), ex situ S/S contaminants are physically bound or enclosed within a stabilized mass (solidification), or chemical reactions are induced between the stabilizing agent and contaminants to reduce their mobility (stabilization). Ex situ S/S, however, typically requires disposal of the resultant materials. Under CERCLA material can be replaced on site.

There are many innovations in the stabilization and solidification technology. Most of the innovations are modifications of proven processes and are directed to encapsulation or immobilizing the harmful constituents and involve processing of the waste or contaminated soil. Nine distinct innovative processes or groups of processes include: (1) bituminization, (2) emulsified asphalt, (3) modified sulfur cement, (4) polyethylene extrusion, (5) pozzolan/Portland cement, (6) radioactive waste solidification, (7) sludge stabilization, (8)soluble phosphates, and (9) vitrification/molten glass.

Typical ex situ S/S is a short- to medium-term technology.

Bituminization

In the bituminization process, wastes are embedded in molten bitumen and encapsulated when the bitumen cools. The process combines heated bitumen and a concentrate of the waste material, usually in slurry form, in a heated extruder containing screws that mix the bitumen and waste. Water is evaporated from the mixture to about 0.5% moisture. The final product is a homogenous mixture of extruded solids and bitumen.

Emulsified Asphalt

Asphalt emulsions are very fine droplets of asphalt dispersed in water that are stabilized by chemical emulsifying agents. The emulsions are available as either cationic or anionic emulsions. The emulsified asphalt process involves adding emulsified asphalts having the appropriate charge to hydrophilic liquid or semiliquid wastes at ambient temperature. After mixing, the emulsion breaks, the water in the waste is released, and the organic phase forms a continuous matrix of hydrophobic asphalt around the waste solids. In some cases, additional neutralizing agents, such as lime or gypsum, may be required. After given sufficient time to set and cure, the resulting solid asphalt has the waste uniformly distributed throughout it and is impermeable to water.

Modified Sulfur Cement

Modified sulfur cement is a commercially-available thermoplastic material. It is easily melted (127° to 149° C (260° to 300° F)) and then mixed with the waste to form a homogenous molten slurry which is discharged to suitable containers for cooling, storage, and disposal. A variety of common mixing devices, such as, paddle mixers and pug mills, can be used. The relatively low temperatures used limit emissions of sulfur dioxide and hydrogen sulfide to allowable threshold values.

Polyethylene Extrusion

The polyethylene extrusion process involves the mixing of polyethylene binders and dry waste materials using a heated cylinder containing a mixing/transport screw. The heated, homogenous mixture exits the cylinder through an output die into a mold, where it cools and solidifies. Polyethylene's properties produce a very stable, solidified product. The process has been tested on nitrate salt wastes at plant-scale, establishing its viability, and on various other wastes at the bench and pilot scale.

Pozzolan/Portland Cement

Pozzolan/Portland cement process consists primarily of silicates from pozzolanic-based materials like fly ash, kiln dust, pumice, or blast furnace slag and cement-based materials like Portland cement. These materials chemically react with water to form a solid cementious matrix which improves the handling and physical characteristics of the waste. They also raise the pH of the water which may help precipatate and immobilize some heavy metal contaminants. Pozzolanic and cement-based binding agents are typically appropriate for inorganic contaminants. The effectiveness of this binding agent with organic contaminants varies.

Radioactive Waste Solidification

In radioactive waste solidification (Grouting/Other) treatment, solidification additives are used to form a uniform and stable matrix to encapsulate radioactive waste materials. Assemblies include pumps for liquids or slurries, conveyors for sludges or solids, storage silos, weigh feeders, piping, mixers and disposal or storage.

Sludge Stabilization

The sludge stabilization process is the addition of a reagent, either slags or cementitious materials, to sludge to transform the material so that the hazardous constituents are in their least mobile or toxic form. Sludges which leach heavy metals or other contaminants are often stabilized to immobilize the hazardous constituents.

Soluble Phosphates

The soluble phosphates process involves the addition of various forms of phosphate and alkali for control of pH as well as for formation of complex metal molecules of low-solubility to immobilize (insolubilize) the metals over a wide pH range. Unlike most other stabilization processes, soluble phosphate processes do not convert the waste into a hardened, monolithic mass. One application of soluble phosphates and lime is in stabilizing fly ash by immobilizing the lead and cadmium in the ash.

Vitrification/Molten Glass

Vitrification, or molten glass, processes are solidification methods that employ heat up to 1,200° C to melt and convert waste materials into glass or other glass and crystalline products. The high temperatures destroy any organic constituents with very few byproducts. Materials, such as heavy metals and radionuclides, are actually incorporated into the glass structure which is, generally, a relatively strong, durable material that is resistant to leaching. In addition to solids, the waste materials can be liquids, wet or dry sludges, or combustible materials. Borosilicate and soda-lime are the principal glass formers and provide the basic matrix of the vitrified product.

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Synonyms: **DSERTS Code:** M13 (Vitrification)
N11 (Solidification/Stabilization)

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Applicability: The target contaminant group for ex situ S/S is inorganics, including radionuclides. Most S/S technologies have limited effectiveness against organics and pesticides, except vitrification which destroys most organic contaminants.

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Limitations: Factors that may limit the applicability and effectiveness of the process include:

- Environmental conditions may affect the long-term immobilization of contaminants.
- Some processes result in a significant increase in volume (up to double the original volume).
- Certain wastes are incompatible with different processes. Treatability studies are generally required.
- Organics are generally not immobilized.
- Long-term effectiveness has not been demonstrated for many contaminant/process combinations.

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Data Needs:

A detailed discussion of these data elements is provided in Subsection 2.2.1 (Data Requirements for Soil, Sediment, and Sludge). Soil parameters that must be determined include particle size, Atterberg limits, moisture content, metal concentrations, sulfate content, organic content, density, permeability, unconfined compressive strength, leachability, microstructure analysis, and physical and chemical durability.

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Performance Data:

The performance of ex situ S/S is dependent on the type of S/S process used.

DOE has demonstrated the Polyethylene Encapsulation of Radionuclides and Heavy Metals (PERM) process at the bench scale. The process is a waste treatment and stabilization technology for high-level mixed waste. Specific targeted contaminants include radionuclides (e.g., cesium, strontium, and cobalt), and toxic metals (e.g., chromium, lead, and cadmium). Scale-up from bench-scale tests has demonstrated the feasibility to process waste at approximately 2,000 lb/hr. The scale-up feasibility tests have successfully demonstrated the potential to encapsulate at least 60 wt% nitrate salt in polyethylene. Polyethylene waste forms have been demonstrated to exceed Nuclear Regulatory Commission, EPA, and Department of Transportation waste form criteria. Waste forms containing up to several thousand ppm of toxic-metal contaminants have passed the EPA's TCLP.

DOE also demonstrated the arc melter vitrification process, which is capable of melting soil and metals, pyrolizing or oxidizing residual organics, melting structural metals from melted slag (silica and metal oxides), and partitioning transuranic (TRU) waste into slag phase. Durability tests with the resultant slag showed an approximately order of magnitude reduction in leachability when compared with high-level borosilicate glass.

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Cost:

Ex situ solidification/stabilization processes are among the most mature remediation technologies. Representative overall costs from more than a dozen vendors indicate an approximate cost of under $110 per metric ton ($100 per ton), including excavation.

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Site Information:

- **EPA *SITE* Demo**: Robins AFB, Macon, GA
- **EPA *SITE* Demo**: Selma Pressure Treating Selma, CA
- **EPA *SITE* Demo**: Portable Equip. Salvage Co. Clackamas, OR
- **Navy Demo:** Naval Const. Battalion Ctr. Port Hueneme, CA
- Imperial Oil Co./Champion Chemical Co. Superfund Site Morganville, NJ
- Small Arms Range, Naval Air Station Mayport, FL
- Davis-Monthan AFB
- **DOI Demo**: Salt Lake City Research Center
- **DOI Demo**: Albany Metallurgy Research Center, OR
- **EPA & DOE Demo:** Component Development & Integration Facility, MT
- NEL Demo: NAS North Island Installation Restoration (IR) Site 11, CA
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4.29 Thermal Desorption

(Ex Situ Soil Remediation Technology)

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Technology	Description
Soil, Sediment, and Sludge	
3.6 Ex Situ Thermal Treatment (assuming excavation)	
4.29 Thermal Desorption	Wastes are heated to volatilize water and organic contaminants. A carrier gas or vacuum system transports volatilized water and organics to the gas treatment system.

Description:

Thermal desorption is a physical separation process and is not designed to destroy organics. Wastes are heated to volatilize water and organic contaminants. A carrier gas or vacuum system transports volatilized water and organics to the gas treatment system. The bed temperatures and residence times designed into these systems will volatilize selected contaminants but will typically not oxidize them.

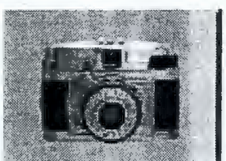

Figure 4-29a: Typical High Temperature Thermal Desorption Process

Two common thermal desorption designs are the rotary dryer and thermal screw. Rotary dryers are horizontal cylinders that can be indirect- or direct-fired. The dryer is normally inclined and rotated. For the thermal screw units, screw conveyors or hollow augers are used to transport the medium through an enclosed trough. Hot oil or steam circulates through the auger to indirectly heat the medium. All thermal desorption systems require treatment of the off-gas to remove particulates and contaminants. Particulates are removed by conventional particulate removal equipment, such as wet scrubbers or fabric filters. Contaminants are removed through condensation followed by carbon adsorption, or they are destroyed in a secondary combustion chamber or a catalytic oxidizer. Most of these units are transportable.

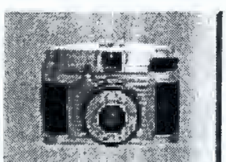

Figure 4-29b: Typical Low Temperature Thermal Desorption Process

Three types of thermal desorption are available and briefly described as following:

1. Direct Fired: Fire is applied directly upon the surface of contaminated

media. The main purpose of the fire is to desorb contaminants from the soil though some contaminants may be thermally oxidized.

2. Indirect Fired: A direct-fired rotary dryer heats an air stream which, by direct contact, desorbs water and organic contaminants from the soil. The Low Temperature Thermal Aeration (LTTA®) developed by Canonie Environmental Services Corporation is a good example of indirect fired system which has been successfully used to remove DDT family compounds from soil.
3. Indirect Heated: An externally fired rotary dryer volatilizes the water and organics from the contaminated media into an inert carrier gas stream. The carrier gas is later treated to remove or recover the contaminants. XTRAX™ thermal Desorption System is a process using indirect heated desorption followed by a high-energy scrubber gas treatment, which successfully removed >99% of PCB from contaminated soil.

Based on the operating temperature of the desorber, thermal desorption processes can be categorized into two groups: high temperature thermal desorption (HTTD) and low temperature thermal desorption (LTTD).

High Temperature Thermal Desorption (HTTD)

HTTD is a full-scale technology in which wastes are heated to 320 to 560 °C (600 to 1,000 °F). HTTD is frequently used in combination with incineration, solidification/stabilization, or dechlorination, depending upon site-specific conditions. The technology has proven it can produce a final contaminant concentration level below 5 mg/kg for the target contaminants identified.

Low Temperature Thermal Desorption (LTTD)

In LTTD, wastes are heated to between 90 and 320 °C (200 to 600 °F). LTTD is a full-scale technology that has been proven successful for remediating petroleum hydrocarbon contamination in all types of soil. Contaminant destruction efficiencies in the afterburners of these units are greater than 95%. The same equipment could probably meet stricter requirements with minor modifications, if necessary. Decontaminated soil retains its physical properties. Unless being heated to the higher end of the LTTD temperature range, organic components in the soil are not damaged, which enables treated soil to retain the ability to support future biological activity.

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Synonyms:

DSERTS Code: N12 (Thermal Desorption).

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Applicability:

Thermal desorption systems have varying degrees of effectiveness against the full spectrum of organic contaminants.

The target contaminant groups for LTTD systems are nonhalogenated VOCs and fuels. The technology can be used to treat SVOCs at reduced effectiveness.

The target contaminants for HTTD are SVOCs, PAHs, PCBs, and pesticides; however, VOCs and fuels also may be treated, but treatment may be less cost-effective. Volatile metals may be removed by HTTD systems. The presence of chlorine can affect the volatilization of some metals, such as lead. The process is applicable for the separation of organics from refinery wastes, coal tar wastes, wood-treating wastes, creosote-contaminated soils, hydrocarbon-contaminated soils, mixed (radioactive and hazardous) wastes, synthetic rubber processing waste, pesticides and paint wastes.

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Limitations:

Factors that may limit the applicability and effectiveness of the process include:

- There are specific particle size and materials handling requirements that can impact applicability or cost at specific sites.
- Dewatering may be necessary to achieve acceptable soil moisture content levels.
- Highly abrasive feed potentially can damage the processor unit.
- Heavy metals in the feed may produce a treated solid residue that requires stabilization.
- Clay and silty soils and high humic content soils increase reaction time as a result of binding of contaminants.

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Data Needs:

A detailed discussion of these data elements is provided in Subsection 2.2.1 (Data Requirements for Soil, Sediment, and Sludge). In addition to identifying soil contaminants and their concentrations, information necessary for engineering thermal systems to specific applications include soil moisture content and classification, determination of boiling points for various compounds to be removed, and treatability tests to determine the efficiency of thermal desorption for removing various contaminants at various temperatures and residence times. A sieve analysis is needed to determine the dust loading in the system to properly design and size the air pollution control equipment.

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Performance Data:

Most of the hardware components for thermal desorption systems are readily available off the shelf. All ex situ soil thermal treatment systems employ similar feed systems consisting of a screening device to separate and remove materials greater than 5 centimeters (2 inches), a belt conveyor to move the screened soil from the screen to the first thermal treatment chamber, and a weight belt to measure soil mass. Occasionally, augers are used rather than belt conveyors, but either type of system requires daily maintenance and is subject to failures that shut the system down. Soil conveyors in large systems seem more prone to failure than those in smaller systems. Size reduction equipment can be incorporated into the feed system, but its installation is usually avoided to minimize shutdown as a result of equipment failure.

Many vendors offer LTTD units mounted on a single trailer. Soil throughput rates are typically 13 to 18 metric tons (15 to 20 tons) per hour for sandy soils and less than 6 metric tons (7 tons) per hour for clay soils when more than 10% of the material passes a 200-mesh screen. Units with capacities ranging from 23 to 46 metric tons (25 to 50 tons) per hour require four or five trailers for transport and 2 days for setup.

The time to complete cleanup of the "standard" 18,200-metric ton (20,000-ton) site using HTTD is just over 4 months.

Soil storage piles and feed equipment are generally covered as protection from rain to minimize soil moisture content and material handling problems.

Soils and sediments with water contents greater than 20 to 25% may require the installation of a dryer in the feed system to increase the throughput of the desorber and to facilitate the conveying of the feed to the desorber. Some volatilization of contaminants occurs in the dryer, and the gases are routed to a thermal treatment chamber.

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Cost:

Rates charged to remediate petroleum hydrocarbon contaminated soil range from \$45 to \$330 per metric ton (\$40 to \$300 per ton) of soil. Of this cost, approximately \$20 to \$35 per metric ton (\$15 to \$30 per ton) is required for direct operating costs such as utility consumption and repair. Vendors typically perform preventive maintenance, such as lubrication, on a daily basis. Unit transportation and setup costs are typically \$3.30 to \$5.50 per metric ton (\$3 to \$5 per ton), seldom exceeding a mobilization cost of \$200,000. Excavation of contaminated soil and the replacement of the treated soil costs approximately \$6 to \$11 per metric ton (\$5 to \$10 per ton).

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Site Information:

- EPA Remedial Action: McKin, ME
- EPA Remedial Action: Otteti & Goss, NH
- EPA Remedial Action: Outboard Marina, Waukegan Harbor (OU 3), IL
- EPA Remedial Action: Cannon Engineering/ MA
- EPA Removal Action: Drexler RAMCOR, WA
- **EPA Demo**: ReSolve, Inc., Superfund Site, MA
- **EPA Demo**: Wide Beach Development Superfund Site, NY & Outboard Marine Corp., IL

- **EPA Demo**: Niagara-Mohawk Power Co., NY
- **EPA Demo**: Pesticide Site, AZ
- **Army Demo**: Letterkenny Army Depot, PA
- **EPA & Army Demo**: Tinker AFB, OK & Anderson Development Co. Superfund Site, MI
- **EPA *SITE* Demo**: EPA Combustion Research Facility, Jefferson, AK
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- Escambia Wood Treating Company, Superfund Site, Pensacola, FL
- Pristine, Inc., Reading, OH
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