Stabilization and Solidification (S/S)

The purpose of S/S is to: (1) improve the handling and physical characteristics of the waste (remove free liquids prior to landfill disposal); (2) decrease the surface area of waste across which loss of contaminants can occur, and/or (3) to limit the solubility of hazardous compounds in the waste.

**Stabilization** limits the solubility or mobility of contaminants by adding materials such as lime to precipitate metals, or a sorbent added to organic waste. The added chemical can change the pH, cause precipitation reactions, and reduce contaminant solubility.

**Solidification** produces a solid block of waste material with high structural integrity, also called a monolith, where the contaminants are locked into the solid matrix.

* S/S has been used at >25% of Superfund sites
* S/S is listed as “best demonstrated available technology” (BDAT) for some RCRA wastes
* use of S/S has increased significantly since the Land Ban on disposal of hazardous waste containing free liquids in any landfill (under HSWA 1984)

There are three general methods or types of additives:
- inorganic additives - cement or pozzolanic (most widely used)
- organic additives - thermoplastic, macroencapsulation, polymerization, clay  
  generally more expensive than inorganics; example = asphalt
- vitrification - melt and fuse materials into a non-crystalline, amorphous form (glass)

The performance of the S/S process is evaluated by 2 types of tests:
- physical tests: index property (particle size of material pre treatment, helps determine how much additive needed), bulk density, permeability (final <10^-5 cm/s recommended), strength, and durability (pre and post stabilization)
- chemical tests: leaching or extraction of hazardous compounds from the post-stabilized waste  
  examples include EP Tox, TCLP, among others

Toxicity Characteristics Leaching Procedure (TCLP): regulatory test used to evaluate the effectiveness of the solidification/stabilization process.

1. Crush stabilized material to particle size <9.5 mm (conservative, since as the particle size decreases the amount of compounds leached out with increase)
2. In a closed flask without headspace mix 20 g weak acetic acid (pH 3 to 5) with 1 g crushed sample on rotary shaker at 30 rpm for 18 hours at 22°C.
3. Sample final liquid, filter, and analyze for metals and organics (generally all the compounds regulated in drinking water). If the concentrations of metals and/or organics exceed the “TCLP regulatory level - which is 100x drinking water concentrations - then the final material fails the safety requirements.

**does it represent potential concentrations in the groundwater? why or why not?**

Factors that influence the performance of S/S and selection of which method include:

1. interfering agents which prevent proper set or curing, including organics (oils, grease, phenols, chlorinated solvents) and inorganics (sulfate, phosphate)
2. gas emissions - since generally exothermic reactions, heat is generated and some volatilization of toxics can occur
3. final strength - decreased by organics

Most Traditional: cement  
Good for acids, heavy metals, radioactive wastes; incompatible with solvents, oils, organics, halogenated compounds (low concentrations may be o.k. such as less than 500 ppm in soil PCBs)  
low cost, high strength, low permeability (decrease permeability to 10^-8 cm/s), low tech  
adds weight and volume (bulk; 1 to 100%), vapor release potential, subject to acid leaching  
generally 7 to 20% of cement is added to the waste  
additives such as fly ash (usually 15 to 30%), asbestos, and plastics may add strength

Thermoplastic: asphalt  
dry waste and mix with asphalt at 1:1 ratio  
compatible with radioactive, metals  
not good for organics, due to vapor emission and fire concerns
Vitrification: to change to a glassy state by heating
ex situ - treat medical waste, asbestos, sludges, soil, incinerator ash, etc.

a. Vitrification with Natural Gas Energy Source

- waste volume reductions as high as 75%; capital cost $2M to $2.5M; treats 250 kg/hr waste;
- operating cost $100 to $420 per ton

Elements:
1. Feed preparation: counter-current rotary drum dryer, auger
2. preheater: temp. 1100°F to gasify organics, which can then be used as fuel
3. vitrifier/converter: 2700°F, fueled by oxygen enriched natural gas; shape molten material as leaving
4. off gas treatment system: gas from vitrifier to heat exchanger, dry baghouse, venturi scrubber and ammonia scrubber, and activated carbon filter

b. Thermal Destruction and Recovery (TDR) - Plasma heating system

- generates inert vitreous material into which metals are bound; “high temp vitrification” simultaneous with gasification;
- 1000 lb/hr waste treatment; 1400 to 1650°C; DRE >99.99999% for organics

in situ (ISV): can treat soil in place, temperatures approx. 3000°F, good for metals and radioactives which are encapsulated in the glass-like structure, while organics are treated by combustion. Invented in 1980, patented by Battelle for DOE in 1983, commercialized in 1989 w/ Geosafe. Can use mobile ISV unit.

1. electrodes inserted into the ground (4; 5-cm dia graphite; bottom 30 cm of electrode uncoated and lowered down as melt proceeds); max. demonstrated width 40’, depth <22”)
2. set a starter path for the electric current on the ground surface between the electrodes of flaked graphite
3. set hood over the ground, with air flow to maintain negative pressure
4. off-gas treatment system: quench, pH-controlled scrubbing, dewatering, heating, particle filtration, and activated carbon adsorption
5. run electricity through electrodes (12.5 to 13.8 kilovolts; 25 kW)
6. melt of soil starts at surface and penetrates down at approx. 1 to 2 inches/hr

(example: used at Hanford for radioactive contaminated soil; also used at sites contaminated with VOCs, metals, biocides, SVOCs, dioxins such as Oak Ridge and the Savannah River Site. At one site 3100 tons of PCB contaminated soil at <12,000 ppm was treated. Still considered an innovative treatment technology, although in 1992 ISV was being used at 3 of 263 sites.)

Options for in situ vitrification include plasma melters or joule-heated systems

- Ionized particles allow plasma to be an excellent conductor of heat and electricity. Plasma vitrification has a higher temperature than joule heated, and allows for higher power densities. In plasma vitrification, an ionized gas (aka plasma) is used to melt the wastes at high temperature.

- Electrons stripped from nuclei and matter exists as a mixture of electrons, nuclei, and atoms. In situ plasma melters operate using a plasma torch to convert electrical energy to thermal energy. Plasma maintains 12,000°C torch, arc 4000-7000°C. Plasma torch is a steel cylinder several inches in diameter and several feet long. Each cylinder contains electrodes, insulators, gas injectors, and water dividers which are integrated into the torch. Two copper electrodes are separated by electrical insulators, with cooling water circulating within the walls of the cylinder to prevent the material from melting at the process temperatures. Gas is released out of the electrode to initiate, stabilize, and replenish the plasma. The gas used can be air, argon, nitrogen, oxygen, or helium. The only thing consumed during operation is the electrodes.
1. Drill boreholes and place casing materials
2. Lower the plasma torch into the hole and activate; organics are destroyed in the relative absence of oxygen via a pyrolysis mode, while inorganics are melted
3. The plasma torch is slowly raised in the borehole, keeping it just above the level of melted soil. The melt can occur below the water table if water recharge to the region can be controlled. Gases formed during the treatment pass up the borehole and are collected in a hood over the treatment area. For large sites, a grid of boreholes is used sequentially to form a glass monolith of the entire site

Could use plasma ISV to create a vertical or horizontal barrier. Melt bottom to top, therefore gases created at atmospheric pressure which limits the explosion potential. Works for depths 50 to 75 ft.