

4-21. Solidification/Stabilization.

a. Process Description.

(1) Solidification/stabilization technology as applied to wastes uses physical and chemical processes to produce chemically stable solids with improved contaminant containment and handling characteristics (Figure 4-23). Waste solidification is the term used to describe the process of sorbing a liquid or semiliquid waste onto a solid medium, such as fly ash, cement, kiln dust, or clay, or otherwise incorporating the waste in a solid matrix. This partial treatment eliminates any free liquid and reduces the risk of spillage or escape of contaminants in any liquid phase.

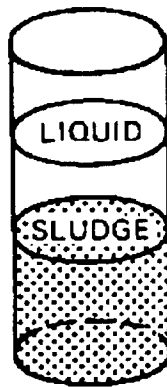
(2) Solidification may involve the addition of cementing agents so that the solid material (with the sorbed liquid) can be formed into a free-standing impermeable monolith. This part of the waste treatment process reduces the surface area across which transfer or loss of pollutants can occur. Stabilization of waste refers to chemical alteration of the waste so as to reduce the potential for escape of contaminants or to lower the toxicity of specific waste components. Both solidification and chemical stabilization result in transformation of liquid or semisolid wastes to an environmentally safer form. For example, metal-rich sludge would be considered solidified if it were mixed with a dry absorber such as fly ash or dry soil. The benefits of solidification could be carried further if the sorbent and waste were cemented into a permeable, monolithic block. The waste would be considered chemically stabilized if the chemical composition of the sludge were altered by the addition of lime ($\text{Ca}(\text{OH})_2$) to raise the pH so that the potential contaminants (toxic metals) were less soluble and hence less easily leached. An absorbing medium can be formulated to take up free liquid and maintain conditions of lowered solubility for the potential contaminants. Cementing agents (organic polymers, pozzolanic materials, or portland cement) can be added to bind the stable, solid waste into a free-standing, relatively impermeable monolith that represents a substantially reduced environmental threat.

(3) Waste solidification/stabilization systems that have potentially useful application in remedial action activities discussed in this paragraph are: sorption, lime-fly ash pozzolan, and pozzolan-portland cement systems. Encapsulation processes such as thermoplastic microencapsulation and macroencapsulation were addressed in paragraph 4-19.

(a) Sorption. Most waste materials considered for solidification/stabilization are liquids or sludges (semisolids). In order to prevent the loss of drainable liquid and improve the handling characteristics of the waste, a dry, solid sorbent is generally added to the waste. The sorbent may interact chemically with waste or may simply be wetted by the liquid part of the waste (usually water) and retain the liquid as part of the capillary liquid. The most common sorbents used with waste include soil and waste products such as bottom ash, fly ash, or kiln dust from cement manufacture.

STABILIZATION

TREATMENT TO REDUCE SOLUBILITY



← EX. pH ADJUSTMENT, CHEMICAL OXIDATION, OR REDUCTION

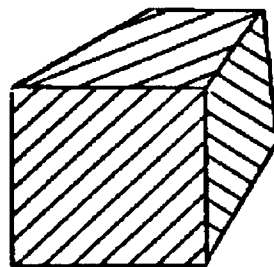
SOLIDIFICATION

SORPTION TO PRODUCE A SOLID WITH NO FREE LIQUID



← EX. MIXING WITH FLY ASH OR CLAY SORBENTS

FORMATION OF MONOLITH WITH REDUCED SURFACE AREA



← EX. ADDITION OF PORTLAND CEMENT (MAY BE ADDED ALONG WITH SORBENTS)

Figure 4-23. Steps in Stabilization/Solidification of Hazardous Wastes

In general, selection of sorbent materials involves tradeoffs between chemical effects, costs, and amounts required to produce a solid product suitable for burial. Table 4-18 summarizes chemical binding properties of natural sorbents for selected waste leach liquids. Where the ability of a sorbent to bind particular contaminants is important to containment, sorbents with specific chemical affinities can be selected. The pH of the waste strongly affects sorption/waste interactions, and pH control is an important part of any sorption process.

Table 4-18. Natural Sorbents and their Capacity for Removal of Specific Contaminants from Liquid Phases of Neutral, Basic, and Acidic Wastes

Contaminant	Neutral waste (calcium fluoride)		Basic waste (metal finishing sludge)		Acidic waste (petroleum sludge)	
Ca	Zeolite	(5054)*	Illite	(1280)	Zeolite	(1390)
	Kaolinite	(857)	Zeolite	(1240)	Illite	(721)
			Kaolinite	(733)	Kaolinite	(10.5)
Cu	Zeolite	(8.2)	Zeolite	(85)	Zeolite	(5.2)
	Kaolinite	(6.7)	Kaolinite	(24)	Acidic F.A.	(2.4)
	Acidic F.A.**	(2.1)	Acidic F.A.	(13)	Kaolinite	(0)
Mg	Basic F.A.	(155)	Zeolite	(1328)	Zeolite	(746)
			Illite	(1122)	Illite	(110)
			Basic F.A.	(176)	Basic F.A.	(1.7)
Zn					Zeolite	(10.8)
					Vermiculite	(4.5)
					Basic F.A.	(1.7)
Ni			Zeolite	(13.5)		
			Illite	(5.1)		
			Acidic F.A.	(3.8)		
F	Illite	(175)	Kaolinite	(2.6)	Illite	(9.3)
	Kaolinite	(132)	Illite	(2.2)	Acidic F.A.	(8.7)
	Acidic F.A.	(102)			Kaolinite	(3.5)
Total CN					Illite	(12.1)
					Vermiculite	(7.6)
					Acidic F.A.	(2.7)
COD	Acidic F.A.	(690)	Illite	(1744)	Vermiculite	(6654)
	Illite	(180)	Acidic F.A.	(1080)	Illite	(4807)
			Vermiculite	(244)	Acidic F.A.	(3818)

* Values represent sorbent capacity in micrograms of contaminant removed per gram of sorbent used.

** F. A. = fly ash. Acidic F.A. = Class F; Basic F.A. = Class C.

(b) Lime-fly ash pozzolan. Solidification/stabilization of waste using lime and pozzolanic material requires that the waste be mixed with a carefully selected, reactive fly ash (or other pozzolanic material) to a pasty consistency. Lime (calcium hydroxide) is blended into the waste-fly ash mixture. Typically 20 to 30 percent lime is needed to produce a strong pozzolan. The resulting moist material is packed or compressed into a mold to cure or is placed in the landfill and compacted.

(c) Pozzolan-portland cement. There are a wide variety of treatment processes that incorporate portland cement as a binding agent. Pozzolan products (materials with fine-grained, noncrystalline, reactive silica) are frequently added to portland cement to react with any free calcium hydroxide and thus improve the strength and chemical resistance of the concrete-like product. In waste solidification, the pozzolan materials (such as fly ash) are often used as sorbents. Much of the pozzolan in waste processing may be waste coated and relatively unreactive. Any reaction that does occur between the portland cement and free silica from the pozzolan adds to the product strength and durability. Waste solidifying formulations based on portland and pozzolan-portland systems vary widely, and a variety of materials have been added to change performance characteristics. These include soluble silicates, hydrated silica gels, and clays such as, bentonite, illite, or attapulgite. Approximate reagent requirements for some example applications are given in Table 4-19.

Table 4-19. Approximate Reagent Requirements for Various Waste Types Using a Portland Cement/Fly Ash Solidification¹

Waste	Kilograms of reagent per liter of waste
Spent brine	3.8
Metal hydroxide sludge	2.4
Copper pickle liquor sludge	1.9
FeCl ₂ pickle liquor sludge (1.5 percent HCl)	3.5
Sulfuric acid plating waste (15 percent (H ₂ SO ₄))	3.8
Oily metal sludge	0.96

¹After Stanczyk, Senefelder, and Clarke (1982). The proportion of portland cement to fly ash was not given.

b. Applications.

(1) Most large, hazardous waste landfills are currently employing sorption to satisfy requirements prohibiting burial of liquids. Nineteen million liters (five million gallons) of oil sludge from a former refinery site was landfilled onsite after treatment with cement kiln dust. The process required 3.71×10^7 kg (40,939 tons) of kiln dust.

(2) Lime-fly ash solidification/stabilization systems have been successfully used in managing hazardous waste, but generally the containment performance is such that a hazardous waste after processing would still be classed as hazardous. Lime-fly-ash-pozzolan-based landfills have been established using liner and monitoring systems to ensure safe disposal. There have been cases where lead wastes were judged nonhazardous after treatment, but in most cases a pozzolan-treated waste is not delisted.

(3) Pozzolan-portland-cement-based systems are among the most versatile. They can neutralize and seal acids and can handle strong oxidizers such as chlorates and nitrates. These methods are also good for solidifying many toxic metals, since at the pH of the cement (pH 9-11), many metals are insoluble carbonates and hydroxides.

c. Advantages/Disadvantages.

(1) Sorption has been widely used to eliminate free water and improve handling. Some sorbents have been employed to limit the escape of volatile organic compounds. Sorbents may also be useful in waste containment when they modify the chemical environment and maintain the pH and redox potential to limit the solubility of the waste. Although sorption eliminates the bulk flow of wastes from the site, in many cases leaching of waste constituents from the sorbent can be a significant source of pollution.

(2) The major advantages of the lime-fly ash solidification/stabilization technique include the ready availability and low cost of materials, and the familiarity of commonly used equipment. A disadvantage is that the solid mass resulting from lime-based solidification is porous. As such, it must either be sealed or placed in a secure landfill to prevent leaching of contained wastes. Another major disadvantage is that sludge or wastes containing organics cannot be treated.

(3) Provided pozzolan-portland cement based systems are used on compatible wastes, the short-term effectiveness can be expected to be quite good. The equipment for cement mixing is commonplace and the process is quite tolerant of chemical variations. However, because cement is a porous solid, contaminants can be leached out of the matrix over time and, therefore, these systems are usually not effective for organic wastes. Although it is possible to seal the outside of a block of cement-solidified wastes using styrene, vinyl, or asphalt to prevent leaching, no commercial systems are available to do this.

d. Data Requirements. The principal data requirements for solidification/stabilization techniques include:

- (1) Waste characteristics (binding agent selection).
 - (a) pH.
 - (b) Buffer capacity.
 - (c) Water content.
 - (d) Total organic carbon.
 - (e) Inorganic and organic constituents.
- (2) Treatability tests (cure time, mix).
 - (a) Leachability.
 - (b) Strength.

e. Design Criteria. The key design parameters for solidification/stabilization techniques include:

- (1) Solidification mixing ratios.
- (2) Curing time.
- (3) Volume increase of solidified product.

f. Evaluation. The evaluation of these factors is dependent on the solidification technology and the specific waste being treated.

4-22. Thermal Destruction.

a. Process Description. Incineration combusts or oxidizes organic material at very high temperatures. The end products of complete incineration are CO₂, H₂O, SO₂, NO₁, and HCl gases. Emission control equipment (scrubbers, electrostatic precipitators) for particulates, SO₂, NO_x, and products of incomplete oxidation are needed to control emissions of regulated air pollutants. Common types of incinerators most applicable to hazardous waste include:

- (1) Rotary kilns.
- (2) Multiple hearth.
- (3) Fluidized bed.
- (4) Liquid injection.

The key features of incineration methods cited previously are summarized in Table 4-20.