Haz Waste: Site Clean-up Methods

- I. In-Situ Vadose Zone Soil
  - –Soil Vapor Extraction, Bioventing, Phyto
  - –Solidification / Stabilization
- 2. In-situ groundwater/aquifer tmt
  - Bioremediation, Phytoremediation
- 3. Ex-Situ contaminated gas treatment
  - incineration, carbon adsorption, biotmt
- 4. Ex-situ soil treatment
  - Solidification / Stabilization
- 5. Ex-situ groundwater
  - Bioremed, phytoremed, P&T

Solidification & Stabilization

- Stabilization = minimize contaminant migration from waste or soil
- Solidification = creating a solid mass
  - –Minimizes migration of contaminants
  - –Structural properties of created solid
- Vitrification = adding heat to soil or solid waste to create a solid "glassy" substance

S&S

- In situ remediation
  - –Used at 42 SF sites to treat 1.3M yd^3 soil
- Ex situ remediation
  - –Used at 119 SF sites to treat 3.7M yd^3 soil
  - –Used for lots of RCRA hazardous waste
    - Land ban on disposal of liquids in landfills due to leachate problem (HSWA)…therefore need to treat waste prior to landfilling
    - For inorganics, S&S is "best available demonstrated technology"
    - For organics, problems with interfering with solid& stab, may volatilize

Test to Determine if Too Much free liquid in sample for landfill disposal

- Paint Filter Test
- Put sample into funnel containing paint filter mesh
- Leave under gravity for 5 min
- If any liquid passes through, the waste fails and must be treated

Mechanisms of S/S

- NOT absorption - "sponge" holding contaminants due to hazard of re-release
- Adsorption - chemical bond between contaminant & "matrix" or binding material
  - –Stabilization and/or solidification
- Macro-encapsulation - waste trapped in MACRO-pores of the solid
  - –Must have SOLIDIFICATION
  - –Potential for re-release if structural solid breaks

Mechanisms of S/S (cont.)

- Micro-encapsulation - trap contaminants in crystalline structure (microscopic pores)
  - –Stabilization &/or solidification
- Precipitation - hydroxides, sulifdes, silicates, carbonates, & phosphates react and product have lower solubility (pH dependent)
  - –Can only use in combination with other methods
  - –Works for metals
- Detoxification - chemical change into less toxic chemical; ex: Cr+6 -> Cr+3

Definitions

- Binder
  - –Adds structural strength
- Sorbent
  - –Keeps contaminants within the matrix

Evaluating effectiveness of S/S

- 1. Solid monolith
  - –Physical tests: strength, durability, density, permeability
- 2. Leachability tests
  - –Put crushed material in an acid solution, and analyze final soluble concs of metals & organics, compare to 100x drinking water stds
  - –TCLP (new)
  - –EP TOX (old)

Leachability Tests

- Harsher conditions than landfill due to low pH (acid)
- Macroencapsulation - benefits not included since material must be crushed, worst case long-term scenario
- Solubilization enhanced due to greater surface area
- Mass : Vol ratio of stabilized material : leaching agent higher in test than landfill (1:20)

Leaching methods comparison

	EP Tox (old)	TCLP (now)
Extr time, hrs	24	18
Mixing	rotary	end-over-end
Sample size	<9.5 mm	<9.5 mm
Closed env.	No	Yes
Init pH extr	5	4.98 or 2.88
Filter acid	0.45 µm	0.70 µm

Leaching Method Comparison: Results on Incinerator Fly Ash

Metal, mg/L	EP Tox (old)	TCLP (new)
Al	**1.97**	0.15
Cd	0	**3.73**
Cu	0.05	0.06
Fe	0.15	0.16
Ni	**0.43**	0.31
Pb	**0.95**	0.17

Additives for S/S

- Cement &/or pozzolanics
  - ✚"Concrete" (calcium silicate)
  - ✚ High strength and low permeability
  - ✚Metals assoc. to insoluble salts with OH, CO3 precipitation
  - ✚Most commonly used
  - ✚Cheapest $30-60/ton, up to $100/ton
  - –Large increase in mass & volume of waste due to extra additives (2-100x)
  - –Organics interfere, and may volatilize out
  - –Susceptible to acid leaching

Additives for S/S

- Thermoplastics
  - –"Asphalt"
  - –Vol additive to waste about 1:1
  - –Compatible for metals, radioactives
  - –Cost somewhat higher than cement
  - –Higher energy use
  - –Higher risk of volatilizing organics away, therefore not good for most organics

Other S/S Additives

- Thermosetting organic polymer
  - –Macroencapsulate waste in sponge-like polymeric material
  - –Low density final material
  - –Less additives needed
- Organically modified clay
  - –Allows adsorption of organic contaminants into clay
- Modified lime (for organics compatibility)

Solidification: Vitrification

- Change to glass by heating and energy input
- Solid monolith created
- Waste volume REDUCTION by as much as 75%
- High cost
- Ex situ - 2 types
- In situ

Ex Situ Vitrification

- Natural Gas as energy source
  - –Remove water in drum dryer
  - –Pre heater at 1100°F to gasify organics (use these with fuel to burn or off gas treatment)
  - –Vitrifier at 2700°F by adding natural gas and oxygen, makes waste molten
  - –Shape molten material and cool
  - –Capital cost $2-2.5M, operating cost $100-420/ton
  - –Treat about 250 kg of waste per hour

Ex Situ Vitrification

- Plasma heating system for Thermal Destruction and Recovery (TDR)
  - –Vitrifier 2550-3000°F
  - –Organics destruction >99.99999% (7 nines)
  - –Plasma arc torch emits UV and IR energy
  - –Cost $750-1820 / ton
  - –230-1000 kg/hr waste treatment rate

In Situ Vitrification (ISV)

- Treats soil in place
- Good for metals and radioactives
- Organics destroyed by combustion
- ~2900-3500°F
- Invented in 1980, patented 1983 by DOE and Batelle, commercialized 1989 by Geosafe
- Used at DOE sites such as Savannah River Site, Oak Ridge, Hanford

In Situ Vitrification (ISV)

- Basic field application
  1. Insert 4 5-cm dia graphite electrodes into ground in a square. Max 40' apart, 22' deep; 30 cm of electrode uncoated and lowered as melt proceeds
  2. Set a starter path of flaked graphite between electrodes
  3. Set hood over ground with air flow to maintain negative pressure
  4. Install off-gas tmt system

In Situ Vitrification

- Basic field application
  5. Run electricity thru electrodes (25 kW; ~13 kV)
  6. Melt of soil starts at surface and penetrates down at approx. 1-2"/hr
     - Air and water in pore space off gassed
     - Final glass porosity ~ 0
     - 4-6 tons soil/hr, 800-1000 kW h/ton soil

Plasma Melted ISV

- Melt bottom to top at higher temperature, 50-75' deep, organics pyrolyzed (low oxygen at depth), inorganics melted
- Process:
  1. Drill borehole and place casing material
  2. Lower plasma torch into hole and activate (21,600°F; inches dia x 3-5 ft long)
  3. Slowly raise torch keeping just above the level of melted material
  4. Collect gases from borehole in a hood

ISV Example

- Problem:
  – Soil contaminated with metals down to 15'
  – Areal extent of contamination 100' x 100'
  – Water table 20 ft deep
- Solution:
  – Std ISV (depth compatible)
  – Space ~34 ft apart squares (<40' limit)
  – Melt ~1.5"/hr = 120 hrs per square
  – 120 hrs/sq * 9 sq = 1080 hrs = 45 days (min)
  – With assembly time, ~50 days

ISV example (cont.)

- Check ton/h rate:
  – 34'x34'x1.5"/hr = 114.5 cf/h = 4.1E6 cm3/h
  – 4.1E6 cm3/hr * 1.6 g/cm3 * 1 ton/1E6 g = 6.56 ton/hr > 6 ton/hr max rec (therefore, ~54 days)
- If initial porosity 0.4, then ground surface will sink 0.4*15 ft = 6 ft