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LAND DISPOSAL OF HAZARDOUS WASTE - THE RESEARCH EFFORT

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USEPA Research Program:

Uncontrolled Hazardous Waste Sites

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INTRODUCTION

Incidents such as Love Canal and Valley-of-the-Drums have projected the environmental significance of uncontrolled hazardous waste sites to the forefront of public and EPA attention. Although these latest developments have resulted in a major commitment by EPA, the Office of Research and Development has been responding to environmental problems from uncontrolled waste sites for several years. Some of these activities are illustrated in Table 1. There are two types of actions that may take place at uncontrolled sites: (1) short-term emergency responses, and (2) permanent long-term remedial actions. Short-term emergency response actions are characterized as follows:

- A high immediate hazard is suspected and quick response action is necessary.
- The expedience of prompt action is more important than the cost-effectiveness of the remedial action employed.
- Threats to the public health and welfare require the correction of obvious pollution problems, e.g., visible surface seeps, failing dikes, spills threatening water supplies, imminent explosion hazards.

- The rapid mobilization of remedial capabilities (especially of mobile equipment) is desirable.
- The duration of intense, on-site response time is short-term (weeks) and the remedial action is particularly important during the early stages of site reclamation.
- Remedial actions will result in the amelioration or reduction of the immediate hazard as opposed to permanent solution.
- The response is limited to small sites or equivalent portions of large sites.
- The decision on the need for response relies upon a level of information available only from reconnaissance investigations.

Permanent long-term remedial actions are characterized as follows:

- Significant hazards exist but acceptable response times are of the order of months.
- The proposed action will result in a permanent closure of the site or a long-term attenuation of the problem.
- Detailed site investigation and monitoring data are essential to define the precise extent of the problem and to determine site hydrogeology, waste characterization, and the nature of the necessary remedial action.
- Cost-effectiveness and permanence of the solution are the essential concerns.
- Remedial action must be applicable to all types of hazardous sites and, especially, to major problem areas and complex sites.

- The use of full-scale on-site containment measures, large-scale modular field-erected treatment/destruction equipment, in-situ treatment, and comprehensive monitoring systems are called for.

The Solid and Hazardous Waste Research Division (SHWRD) of EPA's Municipal Environmental Research Laboratory, conducts research and development to meet the needs of both modes of response. The Disposal Branch (DB) focuses on permanent long-term responses, while the Oil and Hazardous Materials Spills Branch (OHMSB) develops emergency response capabilities.

Specifically, the R&D program focuses on the development of technology and techniques for the prevention, control, and concentration of hazardous substances released to the environment from uncontrolled waste sites, as well as the ultimate disposal of these toxic materials. The program also provides for an assessment of techniques for the restoration of the environment to a healthy state.

EMERGENCY RESPONSE R&D PROGRAM

OHMSB has historically conducted research and development on methods to prevent, contain, separate or remove, and dispose of oil and hazardous materials spills on the sea, inland waters, and land. In recent years, it has been demonstrated that many of the techniques and much of the equipment developed for spills are applicable to uncontrolled hazardous waste site situations. The OHMSB's uncontrolled site program can be divided into seven primary programs as noted in Table 2. Also shown in this table are various systems and items of equipment that have been developed by OHMSB to meet the objectives. The following is a more detailed discussion of some of the equipment and systems listed in Table 2.

- Mobile treatment equipment. OHMSB has developed two mobile trailers that provide a variety of physical and chemical processing systems for on-site treatment of contaminated water. These units have been used to treat water at several uncontrolled sites. A mobile system for regenerating activated carbon has been developed and is being tested.
- Mobile analytical laboratories. Two mobile laboratories have been assembled for on-site analysis of chemicals at uncontrolled sites. One lab is designed for rapid identification of chemicals, enabling investigators to make on-the-spot decisions about cleanup actions. The other is equipped to provide more precise analytical capabilities.
- Portable containment agents. Portable containment systems developed by OHMSB include units that create a barrier of polyurethane foam to contain hazardous materials, and a gelling agent that turns liquid materials into viscous substances that can be removed mechanically.
- Portable collection equipment. Two systems, each consisting of a pump, hoses, and four collapsible reinforced plastic bags with a total capacity of 7,000 gallons, have been used to collect and temporarily store hazardous liquids in emergency situations. The equipment can be used to collect liquid wastes stored in leaking containers or pooled on the ground. One system has a spark-free, battery-powered pump for use in explosive atmospheres.
- Acoustical monitoring. Historically, surface impoundments have been the most common method of disposing of liquid hazardous wastes. Many of these structures are diked or dammed areas that have the potential to cause significant damage if the sides of the impoundment give way.

To test dam stability, OHMSB developed an acoustical monitoring system that senses the sounds that soils make under stress, enabling investigators to predict potential failure. The system has been used successfully at dozens of disposal sites. A microwave version of this system is being designed to detect leakage paths.

- Field detection kits. Several field detection and identification units have been designed by OHMSB. One such kit is used to monitor concentrations of known constituents in a waste leachate stream or in contaminated surface waters. Another field kit has been developed to identify unknown hazardous materials by chemical class and, in some cases, to specifically identify the hazardous materials. In addition, laboratory and field units are available for monitoring the level of metallic compounds in water and/or organophosphate pesticides in water or air.
- Mobile water diversion system. This trailer-mounted pumping and piping system can be used to divert surface water flowing toward an uncontrolled waste site.
- Mobile decontamination station. A semitrailer, containing a clean room, a shower room, and a "dirty" room, is available for decontaminating personnel exposed to toxic chemicals during investigation or remedial action at uncontrolled sites.
- Air pollution control. OHMSB has tested and identified fire-fighting foams that can be used to minimize the air pollution that occurs when toxic liquid chemicals evaporate. In addition, a prototype system has been built to spread pulverized dry ice over a volatile hazardous liquid in order to reduce the rate of vapor release by cooling the hazardous substance.

- Mobile incinerator. Incineration - an important method of ultimate disposal - has traditionally required the transport of wastes to permanent treatment facilities. OHMSB will soon field test a mobile incinerator that will enable toxic wastes and contaminated soil and debris to be safely detoxified on-site.
- Soil treatment units. The treatment of heavily contaminated soils is important for preventing or ameliorating ground and surface water contamination. Three treatment units are currently being developed by OHMSB. One is an in-situ soil washer that will literally cleanse soils by forcing water or neutralizing chemicals through the soil at high pressures, and collecting the wash water in wells or at well points. The wash water can then be decontaminated by standard water treatment methods. Another unit, a mobile grouting system, has been built to confine the pollutants found in contaminated soils. The system first envelopes the area of contamination with a grout curtain. The soil is subsequently decontaminated by injecting appropriate chemicals into contaminated areas. OHMSB is also in the process of building a mobile full-scale unit for scrubbing hazardous wastes from excavated contaminated soil. The unit will use water with additives as required to process several tons per hour of soil from uncontrolled waste sites.
- Sealing of earthen surfaces. Several low-cost methods for sealing surface soil to prevent infiltration are being tested. These include plastic sheets and materials that can be sprayed onto a site to form an impervious layer.

A major focus of the short-term emergency response research program is the development and operational testing of the equipment, as well as evaluation of its effectiveness under different hazardous waste situations. Specific hazardous waste site problems will be explored to provide opportunities for their evaluations. The ultimate goal is the commercialization of the equipment and system and the development of manuals of practice for those personnel involved in emergency situations at hazardous waste sites.

The 1980-1984 research strategy specifies the following research program:

a. Personnel Safety

- o Define and update standard procedures and equipment
- o Develop specialized safety equipment for exposure monitoring protection, and decontamination
- o Develop specially equipped vehicle for safe investigation of waste sites

b. Situation Assessment and Analytical Support

- o Develop/demonstrate rapid and accurate waste identification equipment, techniques, and protocols
- o Develop/demonstrate (pilot-scale) means to evaluate remedial actions and establish a computerized file of such actions
- o Develop/demonstrate field kits for determining waste characterization and mobile labs for situation analysis and assessment
- o Develop/demonstrate equipment to analyze dike stability and impoundment liner integrity
- o Develop and update procedures manual for selection of remedial action for uncontrolled hazardous waste sites

- o Develop and update procedures for identifying cleanup priorities and for defining required extent of cleanup
- o Develop/demonstrate equipment to locate buried wastes and to detect groundwater movement
- o Develop procedures for a uniform classification of hazardous waste sites

c. Concentration and Separation

- o Aqueous wastes, runoff, leachates, and groundwater

  Demonstrate physical-chemical treatment using granular and powdered activated carbon.

  Demonstrate unconventional physical-chemical treatment with powdered activated carbon (including treatment of volatiles).

  Develop/demonstrate techniques for reverse osmosis treatment, steam stripping, ultrafiltration treatment, and oil/water separation.
- o Sludges and sediment - Develop/demonstrate field dewatering techniques
- o Soils - Develop/demonstrate systems for separating contaminants from soils, and use of contaminant levels to classify soils
- o Mixed wastes - Develop/demonstrate techniques for separation of heavy metals from mixed organic wastes and refractory organics from biodegradable organics
- o Gases, vapors - Develop/demonstrate techniques for separation of heavy metals as vapors and particulates in incinerator stack gases, and concentration of contaminants in air emissions from hazardous waste sites

d. Containment and Encapsulation

- o Suppression of volatiles - Develop/demonstrate techniques for temporary vapor suppression for open lagoons and highly contaminated soils
- o Precipitation infiltration controls - Develop/demonstrate emergency groundwater interception system and techniques for rapidly emplaced emergency grout curtains
- o Groundwater control

  Develop/demonstrate emergency groundwater interception systems.

  Develop/demonstrate rapidly emplaced grout curtain techniques for emergency use.
- o Drums

  Develop/demonstrate systems/techniques for patching or recontainerizing leaking or damaged drums.

  Develop/demonstrate system for on-site emptying, washing, and crushing of drums.

  Develop/demonstrate buried drum excavation procedures.
- o Specialized encapsulation techniques - Develop/demonstrate techniques to encapsulate heavy metals into low-leachability synthetic matrices

e. Destruction Techniques

- o Thermal

  Demonstrate mobile systems for incineration and granular activated carbon regeneration.

  Evaluate large commercial thermal systems for off-site destruction of waste.

Develop novel, thermally-based mixed-waste destruction techniques, such as in-situ pyrolysis by RF heating.

Develop/demonstrate feedstock preparation system for mobile incineration system.

Develop/demonstrate large-scale transportable incineration system.

- o Biological

  Develop/demonstrate microbiological techniques for on-site treatment of aqueous wastes, runoff leachates, groundwater, contaminated surface soils, sediments, sludges, and in-place treatment of contaminated deep soils.

  Develop/demonstrate genetically-engineered microorganisms for rapid destruction of hazardous waste.

- o Chemical

  Develop/demonstrate advanced techniques for chemical destruction of selected wastes.

  Develop/demonstrate wet air oxidation techniques for aqueous wastes, runoff, leachates, and groundwater.

PERMANENT LONG-TERM REMEDIAL ACTION R&D PROGRAM

The Disposal Branch (DB) has historically conducted R&D programs to deal with the land disposal of solid waste. The Branch's experience in this area has proven valuable in determining long-term remedial action alternatives at some critical uncontrolled sites (Table 3). Many existing technologies, such as those currently being used for construction, hydrological investigation, wastewater treatment, spill cleanup, and chemical sampling and analysis, can be applied to uncontrolled waste sites. However, their application to uncontrolled hazardous waste sites must be tested and, where necessary, modified. Most needed are more rapid, less expensive, and safer methods for analyzing, testing, and locating wastes; determining the extent of pollution; controlling or eliminating pollution; and assessing public health risks. It is the function of the Disposal Branch to evaluate long-term remedial actions and to develop those modifications necessary to make them most cost-effective for uncontrolled hazardous waste sites. In Table 3 some of the proposed remedial methods are summarized. These methods, either individually or in combination, will be evaluated at hazardous waste sites through direct DB-sponsored activities. The DB has also been extensively involved in providing support and/or technical assistance to EPA 311 actions via the EPA regional offices, as well as enforcement activities. During FY'81 cooperative remedial action activities with other Federal agencies on their hazardous waste problem sites will be initiated. If Superfund legislation passes, opportunities will be expanded to evaluate the effectiveness of remedial actions.

Some specific research activities of the Disposal Branch are:

- Monitoring the effectiveness of remedial action. As long-term remedial action is initiated at various sites, the Disposal Branch will monitor the success of the various actions in reducing environmental contamination. The cost and performance of completed actions will be updated on an annual basis not only for DB and OHMSB activities, but also for private industry efforts where possible, State and local government actions and other groups within EPA. The project will provide a central bank of state-of-the-art information on long-term remedial action which will enable engineers to profit from previous experience and will indicate future research needs.

- Evaluating remedial action alternatives. The Disposal Branch is currently evaluating the results of a remedial action study at a predominantly municipal landfill at Windham, Connecticut. The contractor has studied technologies available for reducing pollution at an existing municipal landfill, and implemented a surface capping technique consisting of a sandwiched section of sand, synthetic membrane, and soil. A guidance manual describing the various alternatives was also developed. The effectiveness of this demonstrated technology, with the exception of cost and safety considerations, is expected to be equally applicable to uncontrolled hazardous waste sites. In 1980, the Disposal Branch will begin two similar projects to evaluate remedial action technologies for a hazardous waste disposal site and a surface impoundment.
- Estimating the costs of remedial action. The Disposal Branch is conducting a project to determine the cost-effectiveness of various remedial actions.
- Evaluating remote sensing technologies for site investigation. In an ongoing project at an uncontrolled site in Coventry, Rhode Island, the Disposal Branch is funding a study to test the effectiveness of ground-piercing radar and other remote sensing devices for determining the location and condition of buried chemical wastes.

The 1980-1984 research strategy for long-term remedial action research and development describes the following program.

a. Full-Scale Corrective Technology Development

- o Identify best practical technology for remedying water and gas pollution from waste disposal sites
- o Remedial action at an uncontrolled hazardous waste disposal site
- o Remedial action at a hazardous surface impoundment/pit, pond, lagoon
- o Special studies relating to the site restoration program of the Department of Defense (Army)

b. Survey, Assessment, Cost

- o Survey of ongoing and completed remedial action projects (annual update)
- o Updating unit operations cost data for remedial actions at uncontrolled sites
- o Summary report of survey technologies

c. Support Technologies Evaluation

- o Uncontrolled hazardous waste site capsule report and Agency response related to "Superfund" legislation
- o Remedial action at a pharmaceutical waste disposal site
- o Remedial action at a chemical waste/drum disposal site
- o Long-term effectiveness of remedial action at a chemical waste/ drum disposal site

d. "In-Situ" Technologies for Hazardous Waste Sites

- o Identify chemical stabilizers best suited for fixating priority pollutants

- Evaluate chemical stabilization injection technology to increase stabilization rates of waste materials
- Evaluate chemical stabilization injection technology relating to waste stabilization by investigating various stabilizers
- Neutralize or modify contaminated soils by chemical/biological in-situ treatment

e. Pilot-Scale Studies

- Develop pilot scale test facility to predict the effectiveness of remedial action schemes
- Construct physical, hydrogeologic model to predict effectiveness of groundwater cutoff systems
- Evaluate concentration as a treatment technology
- Construct a pilot test facility to predict the reactivity with hazardous wastes of various construction materials used in remedial action schemes

SUMMARY

The Solid and Hazardous Waste Research Division is making a two-prong attack on the uncontrolled hazardous waste site problems (emergency response and long-term remedial action), which we feel will result in a consolidated resolution to the uncontrolled hazardous waste problem.

Table 1

Municipal Environmental Research Laboratory Activities
at
Uncontrolled Dump Sites

Site	Problem	Remedial Action
Hopewell, VA	Kepone chemical plant	Carbon treatment
Haverford, PA	Pentachlorophenol contaminated groundwater	Carbon treatment
Dittmer, MO	Illegal waste dump	Carbon treatment
	Discharge of mixed industrial wastes	Excavation of material
Oswego, NY	Bankrupt hazardous waste site	Carbon Treatment
	Discharge of mixed industrial wastes	Lagoon repair
Chattanooga, TN	Bankrupt industrial dump site	Carbon treatment
	Discharge of mixed industrial waste	Mobile lab
Niagara, NY	Leachate from industrial waste site	Carbon treatment Mobile lab
Elizabeth, NJ	Identify drum contents at a bankrupt industrial dump site	Pilot plant Mobile lab Site explosion Carbon treatment
Bartlett, TX	Industrial waste chemical lagoon	Mobile lab
Sharptown, MD	Abandoned dump site containing PCB's and mixed industrial wastes	Mobile lab
Aurora, MO	Illegal dump site containing dioxin	Mobile contamination unit
Niagara Falls, NY	Minimize moisture infiltration	Surface capping
Windham, CT	" " "	" "
Charles City, IA	Leachate generation	In situ stabilization
Wilsonville, IL	Leachate contaminment	Clay liner
Saltville, VA	Mercury discharge	Surface impoundment erosion control
Coventry, RI	Drum disposal site	Non-destructive device for coating drums
Verona, MO	Dioxin disposal	Excavation and removal
Glassboro, NJ	Leachate from co-disposal site	Minimize moisture and stream infiltration
Llangollen, DE	Leachate plume in groundwater	Counter pumping
Edison, NJ	Leachate from co-disposal site	Surface capping and erosion control

Table 2

Short-Term Emergency Response Program
for
Uncontrolled Hazardous Waste Sites

PROGRAM	OBJECTIVES	EQUIPMENT DEVELOPMENT
1. Pre-Response Planning	To prepare materials for use by organizations that respond to hazardous waste site incidents to assist them in maximizing the effectiveness of their responses through coordination and planning.	
2. Safety	To provide a safe working environment for personnel engaged in cleanup operations	Mobile decontamination unit (d), Chemical protective ensemblè (c)
3. Situation Assessment	To provide decision-making managers at uncontrolled hazardous sites with the methods and equipment for assessing the situation.	Cyclic colorimeter (c), Hazardous materials detection kit (c), Organophosphate pesticide detection kit (c), Acoustic emission earth dike assessment system (c), Mobile chemical laboratory (d), Drum sampler (d), Hazardous materials identification kit (o)
4. Containment and Confinement	To limit the spread of a hazardous material in all media: air, soil, surface water, subsurface water, and sediments.	Foam dike system (c), Mobile stream diversion system (d), Portable collection bag system (d) Gelling agency system (d)
5. Concentration and Separation	To collect and concentrate hazardous materials to a minimum practical volume and to separate the material from co-collected air, water, soil or sediments.	Mobile physical/chemical treatment system (c), Mobile soil cleaner (r), Mobile flocculation-sedimentation system (o), Mobile reverse osmosis treatment system (r)

Table 2 (cont'd)

PROGRAM	OBJECTIVES	EQUIPMENT DEVELOPMENT
6. Ultimate Disposal and Destruction	To provide permanent encapsulation or destruction of residuals from cleanup operations, with emphasis on technologies useable on-site.	Mobile incineration system (r), Mobile carbon regeneration system (o)
7. Information Transfer and Processing	To deliver field-ready products of technology development activities in forms acceptable to end users, including commercialization of equipment and manuals of practice for cleanup personnel.	

Key:

c - EPA developed equipment now commercially available
d - EPA developed equipment currently on standby for field demonstration
o - Equipment undergoing operational treating
r - Equipment currently under research and development

TABLE 3. PERMANENT LONG TEP'I REMEDIAL ACTION PROGRAM FOR UNCONTROLLED HAZARDOUS WASTE SITES

Method	Characteristics/Remarks
Surface Water Control	
Surface Seal (A)	Expensive; high upkeep; very hard to place; highly effective; approximately 20 year life
Surface Water Diversion & Collection	Diversion & collection of water to avoid leachate production
Dikes and Berms (A)	Inexpensive; moderate upkeep; very easy to place; fairly effective; temporary structures: prevents excessive erosion
Ditches, Diversions, Waterways (A)	Inexpensive; moderate upkeep; very easy to place; fairly effective; prevents excessive erosion
Chutes and Downpipes (A)	Inexpensive; low upkeep, very easy to place; fairly effective; temporary structures, no special tools or material required
Levees (A)	Moderately expensive; high upkeep; Permanent structures, guard against flooding; effective
Seepage Basins & Ditches (A)	Moderately expensive; high upkeep, easy placement; fairly effective; permanent structures, prone to clogging
Sedimentation Basins/Ponds (A)	Inexpensive; low upkeep; easy placement; fairly effective; easy to design & install, permanent structures
Groundwater Controls	
Impermeable Barriers	Rerouting of groundwater to avoid leachate formation
Slurry Walls (A)	Expensive; very low upkeep; fairly effective; longlasting
Grout Curtains (A)	Very expensive; very low upkeep; hard to place; fairly effective; highly technologic alternative; done by very few companies

Method	Characteristics/Remarks
Sheet Piling (A)	Inexpensive; very low upkeep; very easy to place; fairly effective; used to stop formation of H.W.
Permeable Treatment Beds (A)	Expensive; high upkeep; easy to place; marginally effective; prone to ponding; sensitive
Groundwater Pumping	Lowering of water table to avoid leachate formation and for treatment
Water Table Adjustment (A)	Inexpensive; high upkeep; easy to place; fairly effective; reliable when properly monitored; has a large construction flexibility
Plume Containment (A)	Expensive; high upkeep; easy to place; fairly effective; very flexible as far as design and operation
Contaminated Water Treatment (A)	Expensive; high upkeep; easy to place; fairly effective; highly flexible and reliable
Bioreclamation (A)	Inexpensive; high upkeep; easy to place; fairly effective; fast, safe, doesn't remove all contaminants

Leachate Control

Subsurface Drains (A)	Expensive; high upkeep; easy to place; fairly effective; system requires continuous and careful monitoring, fairly reliable, considerable flexibility available
Drainage Ditches (A)	Inexpensive; extremely high upkeep; easy to place; fairly effective; requires extensive maintenance; useful in collecting side seepage and runoff
Liners (A)	Expensive; moderate upkeep; very hard placement; fairly effective; virtually impossible to use on existing sites, complicated and difficult to place, approximately 20 year life

TABLE 3 Continued

Method	Characteristics/Remarks
Leachate Treatment (A)	Highly dependent on the method, strength of the waste, and desired output
Leachate Recycle (B)	Still in the R&D stage; this is a form of leachate treatment
Gas Migration Control	
Pipe Vents (A)	Moderately expensive; low upkeep; easy to place; fairly effective; forced ventilation is by far the most effective method (over atmospheric dissipation)
Trench Vents (A)	Expensive; moderate upkeep; easy to place; fairly effective; induced draft is by far the most effective method (over atmospheric dissipation. which is somewhat uneffective)
Gas Barriers (A)	Highly dependent on the materials used, expensive and not effective (in general)
Gas Collection Systems (A)	Single-fan/vent collection systems are cheap, effective, & easy to upkeep, but can only be applied to a 5 to 6 acre site, manifold collection system is more complicated, costly, and requires a great deal of upkeep
Gas Treatment Systems (B)	Highly dependent on the method used; site specs will designate the method; generally expensive
Gas Recovery (B)	Recover methane, clean it, combine it with natural gas, and use it for fuel, in its infant state, state of the art is yet to be fully developed
Direct Waste Treatment Methods	
Excavation (A)	Operation that is undertaken to prepare a site for waste disposal: backhoe & dragline are typical excavation tools
Hydraulic Dredging (A)	This is an expensive undertaking; utilizes well-established widely available technology; effective; requires a good deal of equipment

Method	Characteristics/Remarks
Land Disposal (A)	Includes surface impoundments, land-filling, & land spreading; controlled by RCRA; most common disposal form
Incineration (A)	Very versatile; can handle waste in solid, liquid or gaseous state; expensive; causes air pollution; substantial upkeep
Wet Air Oxidation (A)	Usually used with a biotreatment unit; expensive; used to treat wastewater & difficult to dewater sludges
Solidification	Involves sealing the waste in a hard stable mass
Cement-Based Solidification (A)	Involves sealing waste in portland cement; effective; but tends to leach
Lime-Based Solidification (A)	Involves solidification of waste with a lime based medium; creates a porous solid that must be either landfilled or sealed
Thermoplastic Solidification (A)	Involves sealing waste in asphalt bitumen, paraffin, or polyethylene; forms a stable solid which isn't leach prone; expensive
Organic Polymer Solidification (B)	Involes solidification with urea-formaldehyde; substance formed is biodegradable and will readily release pollutants
Self-Cementing Solidification (A)	Has to be a desulfurized sludge that contains a large amount of calcium sulfate or sulfide in order to be solidified; expensive; forms a stable solid
Glassification (B)	Involves combining waste with molten glass; very expensive; very stable
Encapsulation (B)	Complete isolation of the waste in a synthetic encasement, very expensive (requires skilled labor); very stable; yet to be attempted on a large scale

TABLE 3 Continued

Method	Characteristics/Remarks
In-Situ Treatment (C)	Very limited application; site must be well defined, shallow & the extent of contamination small
Solution Mining (C)	Flood the land disposal area with a solvent & collect the elutriate with a series of shallow well joints; inexpensive; only amenable to certain wastes
Neutralization/Detoxification (C)	Inject the land disposal area with a substance that immobilzes or destroys pollutant; must have a degradable waste; expensive
Microbial Degradation (C)	Seeding a waste with microorganisms to achieve degradation; sensitive; expensive
Other Direct Treatment Techniques	Techniques used to control waste from refuse sites
Molten Salt (C)	Combustion of wastes with salt; the salt reacts with undesirable waste by-products; expensive
Plasma Reduction (C)	Any organic waste may be destroyed; done by severing bonds in waste material

Contaminated Water and Sewer Lines

Method	Characteristics/Remarks
In-Situ Cleaning (A)	Methods used to clean, inspect, & repair clogged or leaking lines
Mechanical and Hydraulic Scouring (A)	Removal of pipeline obstacles with devices such as a "snake" or high pressure hydraulic influx
Bucket Dredging and Suction Cleaning (A)	Buckets are drug along the base of sewer pipes thus dredging them; also suction can be used to clean sewer lines of toxic liquid & debris
Chemical Treatment (B)	Foams & gels that absorb & bind liquid pollutants; the matrix formed is then hydraulically flushed

Method	Characteristics/Remarks
Leak Detection & Repair (A)	Location - repairing methods
Pipeline Inspection (A)	Several different techniques are available; such as using dyes, audiophone leak detectors, etc.
Grouting (A)	In-situ treatment of repairing pipe cracks or ruptures with a gel-like grout
Pipe Relining & Sleeving (A)	Very simple & inexpensive sealing alternative; an in-situ operation that coats the inside of pipes; effective results
Removal & Replacement (A)	Very expensive; when no other alternative is left
Contaminated Sediments	
Mechanical Dredging (A)	A viable alternative for shallow small streams; if water flow isn't detoured excessive turbidity results; limited use
Low-Turbidity Hydraulic Dredging (A)	This is an expensive undertaking; utilizes well established technology; effective; requires a good deal of equipment
Dredge Spoil Management (A)	Methods for dewatering, transporting, storing, treating & disposing of contaminated sediments
Dewatering & Transport (A)	Solidifying slurry & loading it on barge, train, or truck such that it can be transported to treatment
Storage & Disposal (A)	Pumped slurry is placed in a containment basin for either permanent disposal or temporary storage
Treatment (A)	Dewatering & stabilization of slurry such that it is suitable for land disposal
Revegetation (A)	When marshland is dredged, it must be refilled with clean fill & revegetated to insure ecological integrity

KEY

A - Commercial Available
B - Research & Development Stage
C - Conceptual

End