

Other Remediation Technologies

To complete the discussion of remediation alternatives for dioxin-contaminated sites, this chapter presents techniques that, rather than treating or destroying dioxins, are used to concentrate, stabilize, or store the contaminated material. Such approaches may be used either in conjunction with treatment or as a simpler alternative.

ONSITE SOIL WASHING TECHNOLOGIES

Soil can be washed with solvents or “soaps” (surfactants) to extract contaminants into the liquid stream, thus reducing the volume to be treated. Soil washing, though relatively new in the remediation field (as in aquifer restoration), is commonly used in mining operations. At present, however, there are no full-scale soil washing systems for treating dioxin-contaminated soil commercially available in the United States.¹

Testing and Availability of Soil Washing Technology

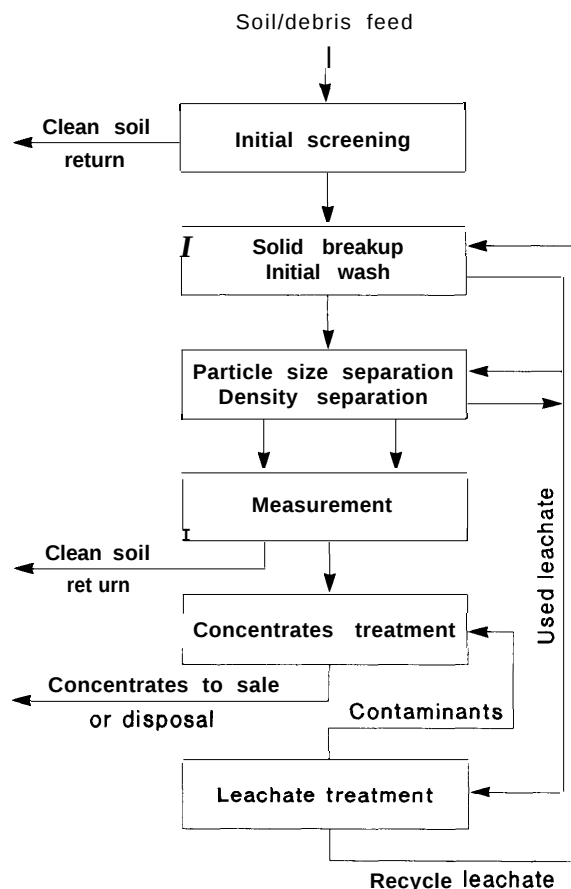
One soil washing technique currently available, which may be applicable to dioxin-contaminated soil, is offered by Westinghouse Electric Corp. (WEC). According to WEC, this method has been proved effective in the treatment of soil contaminated with organic chemicals, heavy metals, and even radionuclides. Another technique is expected to be offered soon by BioTrol, Inc. (Chaska, Minnesota), for the treatment of soil contaminated with organic pollutants, including polychlorinated biphenyls (PCBs) and pesticides.

No information from full-scale studies on the efficacy of soil washing for dioxins in full-scale studies exists at the present time. A 1990 review of available technologies best equipped for cleaning up the U.S. Navy site in Guam found soil washing incapable of treating the highly PCB-contaminated soil present at the site.² That review, however, did not consider the WEC and BioTrol soil washing methods.

Westinghouse Electric Soil Washing Technology

The WEC process shown in figure 4-1 consists of several interconnected treatment units, including a particle separator (by size and density) and chemical extractors containing soaps to cleanup the soil. One advantage of this process is that because contaminated soil is treated in a slurry, air emissions and water discharges are eliminated. After being washed, soil is returned to the site and the concentrated residuals are processed through incineration, recycling, or stabilization techniques.

Figure 4-1—Westinghouse Soil Washing Process



SOURCE: Westinghouse Electric Corp., "Soil Washing Applicability and Treatability Studies," undated.

¹John Sheldon, BioTrol, Inc., personal communication, Apr. 1, 1991.

²Naval Civil Engineering Laboratory, "Engineering Evaluation/Cost Analysis (EE/CA) for the Removal and Treatment of PCB-Contaminated Soils at Building 3009 Site," Naval Civil Engineering Laboratory, Port Huene, CA, July 3, 1990, p. 7.

The chemical composition of the soaps (leach solutions) can be modified to address specific site needs. Processes used by Westinghouse have been employed in Europe. They were used in Germany to remove 98 percent of the polynuclear aromatics from soil (at HWZ Bodenmsanering), and more than 90 percent of the heavy metals and organics (at a site in Hamburg).

The process can be varied to address specific site conditions because studies have indicated that:

1. organics concentrate in clay, silt, and humic materials;
2. PCBs and other organic components can be leached out with caustic agents (sodium hydroxide, sodium carbonate) and surfactants;
3. the abrasive nature of soil particles can be used to improve the efficiency of the technology; and
4. heavy metals and radionuclides are usually more dense than soil.

The major steps in the WEC soil washing technique include the excavation of soil and the removal of large rocks and debris; sorting of soils by placing them in a rotating drum/vibrating screen device for size separation; and washing of the large, and probably uncontaminated, soil particles and debris (greater than 2 millimeters) with soap solution. This phase is completed by rinsing and returning large soil particles to the site.

During the second phase, the remaining contaminated soil and debris are passed through a mineral processing unit where they are exposed to soap solution and the fines present are separated. Processed soils are then washed, monitored, and finally returned to the site. The metal fines and soap (mixed with organic contaminants removed from the soil) from the mineral processor are passed through a precipitation tank, where they are exposed to precipitation agents to induce chemical separation. The clean soap solution is sent to make-up tanks for recycling; metal fines, if cleaned, are shipped for

recycling, and organic concentrates are sent to biotreatment or incineration units.³

BioTrol Soil Washing Technology

The BioTrol technology—a patented process initially designed to treat soils contaminated with wood preserving waste—can be used to wash soil containing hydrocarbons, pentachlorophenol, and pesticides. The BioTrol system (see figure 4-2) uses a high-intensity, countercurrent scrubber to separate finer soil particles containing the pollutants of concern from coarser soil material; contaminants that adhere to coarser materials are freed by the abrasive scouring action of the soil particles. The efficiency of the soil washing solution may be improved by: 1) adding detergents, surfactants, or chelating agents; or 2) adjusting pH and temperature. Effluents from the BioTrol system are clean soil (which can be redispersed), process water (which can be recycled or biologically treated), and contaminated soil fines. Depending on the type of pollutants present, these soil fines may be landfilled, incinerated, stabilized, or treated biologically.⁴

Preliminary results from a 1989 EPA-sponsored demonstration at the MacGillis & Gibbs Superfund site in New Brighton, Minnesota show the ability of the BioTrol technology to reduce the pentachlorophenol concentration in soil by 91 to 94 percent. The bench-scale unit tested had a treatment capacity of 12,000 pounds per day.⁵

SOLIDIFICATION AND STABILIZATION TECHNOLOGIES

Solidification and stabilization (S/S) technologies have been employed in the United States for more than 20 years to treat certain liquid industrial chemical wastes; more recently, however, their use has been expanded to treat contaminated soil and incineration residues.⁶ S/S techniques focus primarily on limiting the volatility or mobility of contami-

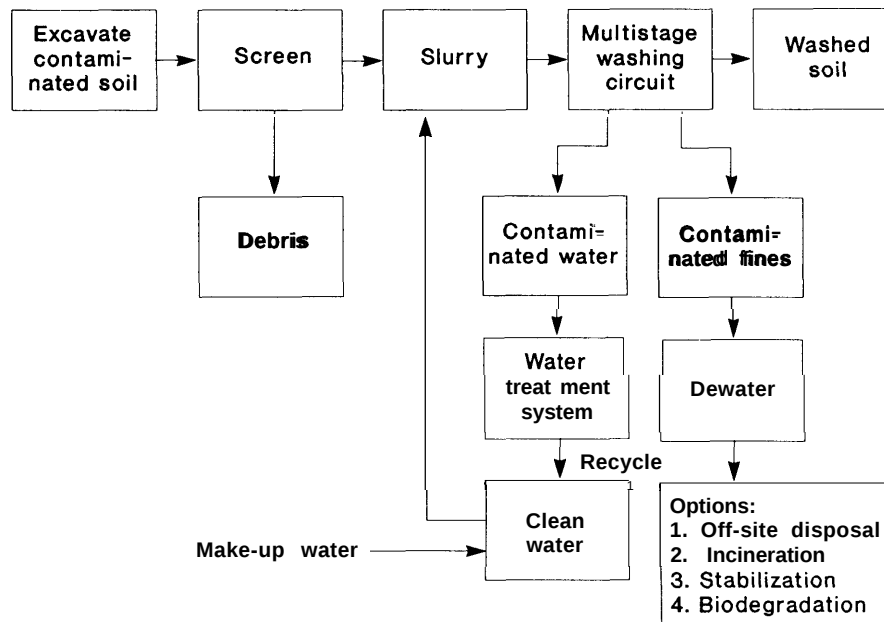
³A full-scale remediation project with WEC process is being carried out at a uranium mining site in Bruni, TX. Westinghouse Electric Corp., "Soil Washing Applicability and Treatability Studies," undated, D.C. Grant, E.J. Lahoda, and A.D. Dietrich, "Remediation of Uranium and Radium Contaminated Soil Using the Westinghouse Soil Washing Process," paper presented at the Seventh Annual DOE Model Conference, Oak Ridge, TN, Oct. 14-17, 1991.

⁴U.S. Environmental Protection Agency, Office of Research and Development, Risk Reduction Engineering Laboratory, *Technology Profiles*, EPA/540/5-90/006 (Cincinnati, OH: November 1990), pp. 26-27; John K. Sheldon, BioTrol, Inc., personal communication, July 23, 1991.

⁵Ibid., p. 27.

⁶U.S. Environmental Protection Agency, Office of Research and Development, Risk Reduction Engineering Laboratory, *Immobilization Technology Seminar*, CERL-89-222 (Cincinnati, OH: October 1989), pp. 1-3.

Figure 4-2—Soil Washing System Offered by BioTrol, Inc.



SOURCE: U.S. Environmental Protection Agency, Office of Research and Development, Risk Reduction Engineering Laboratory, *Technology Profiles*, EPA/540/5-90/006 (Cincinnati, OH: November 1990).

nants present in the medium, generally by physical means rather than by chemical reaction. This goal is achieved by one or more of the following: improving the handling and physical characteristics of the waste; decreasing the surface area of the waste mass; converting the contaminated medium into a solid block; limiting the volatility of hazardous constituents; or detoxifying the contaminants present in the waste to be treated.⁷

Historically, the physical and chemical bonding involved in complex stabilization reactions has not been rigorously researched and understood by most practitioners. Many view S/S treatments as “low tech, no-tech, or pseudo-tech.”⁸ More damaging, however, is the fact that claims by certain vendors on the successful application of their particular techniques are largely unsubstantiated.⁹

The long-term effectiveness of S/S treatment has always been surrounded by uncertainty. Among the factors contributing to this are: the difficulty of determining what actually occurs under field conditions; the difficulty of reproducing in the laboratory the role played by S/S materials in soil and waste; the potential for cement bonding to be retarded by contaminants; and the varying nature and size of soil particles at contaminated sites. Heat produced by the reaction between S/S chemicals and the waste may also induce the volatilization of organic compounds.¹⁰ As a consequence, it is extremely important that bench tests be performed prior to S/S treatment to determine: 1) proper type and amount of additive, 2) applicable mixing and curing conditions, and 3) the type of long-term monitoring needed.¹¹ Attention to effluent treatment is not

⁷U.S. Environmental Protection Agency, Office of Research and Development, Risk Reduction Engineering Laboratory, *International Waste Technologies/Geo-Con In Situ Stabilization/Solidification—Applications Analysis Report*, a Superfund Innovative Technology Evaluation (SITE) report, EPA/540/A5-89/004 (Cincinnati, OH: August 1990), p. 6.

⁸Jeffrey P. Newton, *The Derivation of Relevant Chemically Reactive Structures for the Fixation of Organics and Inorganics*, International Waste Technologies, Wichita, KS, January 1991, p. 2.

⁹Jeffrey P. Newton, President, International Waste Technologies, personal communication Apr. 19, 1991.

¹⁰U.S. Environmental Protection Agency, op. cit., footnote 7, p. 16.

¹¹*Ibid.*, pp. 22-23.

necessary because all of the water consumed is used for processing purposes.¹²

According to the U.S. Environmental Protection Agency (EPA), based on the type of additive and processes used, stabilization methods can be organized into at least six different categories:

1. cement;
2. lime plus pozzolans (fly ash, kiln dust, hydrated silicic acid, etc.);
3. thermoplastic (asphalt, bitumen, polyethylene, etc.);
4. thermosetting organic polymers (ureas, phenols, epoxies, etc.);
5. vitrification; and
6. miscellaneous.

Of these groups, only cement-based, quicklime, and vitrification are being researched for their potential application to dioxin-contaminated soil.

Although traditional S/S treatment has been conducted simply by mixing two or more products from the above categories, increasing research has resulted in a series of new products that use additives (e.g., proprietary dispersants and organophilic compounds) mixed with setting agents; these mixtures seem to have a greater potential to bind organics (PCBs, petroleum hydrocarbons, coal tars, and probably dioxin) than most commercially available mixtures.¹³ For now, the challenge, some vendors claim, is being able to determine the extent to which these techniques are effective and, where appropriate mechanisms of evaluation exist, to determine whether these techniques can in fact detoxify dioxins.^{14 15}

EPA has selected S/S as the preferred treatment at several Superfund sites. Selection has occurred most commonly at sites with contaminated soil and acidic sediments known to contain heavy metals, for

example, Sapp Battery (Florida), Marathon Battery (New York), and Independent Nail (South Carolina). EPA has also called for the application of S/S treatment to organic wastes, including PCBs, found at Pepper Steel & Alloys, Inc. (Florida),¹⁶ York Oil (New York), Fields Brook (Ohio), and Liquid Disposal Landfill (Michigan).¹⁷ At the majority of these sites, S/S has been conducted by bulk mixing in a pit or by treatment of waste in a tank following excavation.¹⁸

Testing and Availability of S/S Technology

In 1987, a laboratory study was conducted at three dioxin-contaminated eastern Missouri sites to identify and evaluate S/S technologies capable of eliminating the transport of dioxin from soil due to wind and water erosion. The selected sites were **Minker site** (a residential area known to have soil with 2,3,7,8-tetrachlorodibenzo-p-dioxin (2,3,7,8-TCDD) at 700-ppb (parts per billion) levels, and which could contaminate a nearby creek); **Piazza Road** (2,3,7,8-TCDD was detected at the 640-ppb level); and **Sontag Road** (characterized by very fine soil containing 2,3,7,8-TCDD at 32-ppb levels).¹⁹

As part of the experiment, soil samples from the sites were mixed with varying amounts of Portland cement, emulsified asphalt, and/or lime. The cement/soil mixture was found ineffective because significant amounts of cement became loose after exposure to laboratory conditions that mimicked weathering. Emulsified asphalt, on the other hand, was found to be an effective stabilizer but only after calcitic lime had been added (about 15 percent) to the mixture. Mixing asphalt, lime, and native soil was found to be the most successful S/S technique, allowing dioxin migration only at concentrations below the detection limits.²⁰ (Estimated treatment costs ranged from \$5 to \$10 per cubic meter [emulsified asphalt] to \$11 to \$13 per cubic meter [Portland cement]. An estimated

¹²Ibid., pp. 29-30.

¹³Ibid., p. 7.

¹⁴Although the second factor should not be construed as a primary purpose of S/S technologies, some treatment companies claim that in addition to the cementing action, their processes also affect organic contaminants through chemical interaction.

¹⁵U.S. Environmental protection Agency, op. cit., footnote 7, p. 6; Newton, Op. cit., footnote 8, p. 1.

¹⁶Cleanup at this site consisted of digging up contaminated soil, separating it from debris, mixing it with Portland cement, and returning it to its original site.

¹⁷U.S. Environmental Protection Agency, op. cit., footnote 7, p. 7.

¹⁸Ibid.

¹⁹Paul E. des Rosiers, "Evaluation of Technology for Wastes and Soils Contaminated With Dioxins, Furans, and Related Substances," *Journal of Hazardous Materials*, vol. 14, No. 1, 1987, pp. 121-122.

²⁰Ibid., p. 123.

\$4 to \$8 per cubic meter should be added to these amounts when health and safety costs are considered.) Although these results highlight the potential applicability of asphalt/lime as a temporary remedial measure, additional in depth studies on the long-term performance of these or other more advanced S/S technologies have yet to be conducted.

More recently, the EPA Superfund Innovative Technology Evaluation (SITE) program has undertaken the evaluation of at least seven S/S techniques. Among the methods under consideration, in addition to the quicklime process, are those designed and developed by International Waste Technologies, Inc. (Wichita, Kansas); Silicate Technology, Inc. (Scottsdale, Arizona); Separation & Recovery Systems, Inc. (Irvine, California); Soliditech, Inc. (Houston, Texas); Chemfix Technologies, Inc. (Metairie, Louisiana); and HAZCON, Inc. (Brookshire, Texas).²¹

At present, some S/S techniques have proved effective for stabilizing residues resulting from chemical or thermal treatment of dioxin-contaminated material.

Although no S/S treatment offered to date is considered by EPA to be an "alternative disposal method to incineration,"²² the future of this treatment has some promise. The increasing application of incineration to contaminated materials could also increase the use of stabilization techniques, particularly in those situations in which incinerated ash is prohibited from land disposal because of the hazardous constituents remaining.

EPA QUICKLIME TREATMENT

EPA's interest in evaluating certain mixtures of lime and other alkaline stabilizers originated after observing reductions in PCB levels at those sites in which S/S techniques have been employed. In order to understand the processes involved, EPA's Risk Reduction Engineering Laboratory in Cincinnati, Ohio, contracted with RMC Environmental of West Plains, Missouri, to conduct laboratory research. Although preliminary results show decreases in

PCB levels, EPA scientists who reviewed the report recommended additional evaluation because the method of reduction is still unknown.

In summary, experiments were conducted on synthetic soil by using three specific PCB congeners in an open vessel containing calcium oxide (CaO) and in a closed vessel containing:

- . CaO,
- . cement kiln dust, or
- . a combination of CaO and kiln dust.

Testing in an open vessel in a glove box indicated that significant removal of all three congeners occurred within the first 5 hours at 180 to 200 °C. However, most of the disappearance was attributed to atmospheric releases through dusting, vaporization, and steam stripping. From these results, researchers expected that field demonstrations would result in slower rates of removal than experienced in the laboratory because they would be carried out at much lower temperature. The closed-vessel experiments, on the other hand, were conducted at lower temperature and had significantly lower rates of volatilization and steam stripping. Chemical dechlorination and destruction were found to account for less than 7 percent of the measured removal.²³

EPA plans to support further laboratory investigations to examine the decomposition and volatilization process attributed to quicklime. Field examinations are also planned.²⁴

INTERNATIONAL WASTE TECHNOLOGIES TREATMENT

The International Waste Technologies (IWT) process, advanced chemical fixation, is a cement-based process that uses proprietary additives (organophilic clays) to solidify and stabilize waste, and to promote chemical bonding between the contaminants in the waste and the cement matrix.²⁵ The ability to alter the molecular structure of organic pollutants, including PCBs, has encouraged company officials to conclude that the IWT fixation

²¹U.S. Environmental Protection Agency, op. cit., footnote 6, pp. 1-3.

²²U.S. Environmental Protection Agency, op. cit., footnote 7, p. 20.

²³U.S. Environmental Protection Agency, Office of Research and Development, Risk Reduction Engineering Laboratory, *Status Report: Quicklime Treatment of PCBs* (Cincinnati, OH: May 1991).

²⁴Letter from John Convery, Deputy Director, U.S. EPA Risk Reduction Engineering Laboratory to German Reyes, Office of Technology Assessment, June 11, 1991.

²⁵U.S. Environmental Protection Agency, op. Cit., footnote 7, p. 21.

process “sufficiently bonds and prevents the leaching of the PCB decomposition products, substituted benzenes and phenol compounds.”²⁶

As opposed to all competing S/S techniques, which require excavation, treatment, and redispersion of soil, the IWT process calls for the use of in situ treatment only, thus eliminating the costs of soil excavation, sizing, handling, and redispersion.²⁷ This treatment may be tailored to address the specific types of chemicals requiring treatment.

Of the evaluations performed on the IWT process, the most extensive to date has been the bench-scale demonstration conducted in April 1988, under EPA's SITE program at a General Electric site in Miami, Florida. In addition to evaluating the form of treatment, which consisted of injecting IWT's chemical fixation material into PCB-contaminated soil by use of mixing drills,²⁸ EPA engineers studied all possible reaction mechanisms and the extent of chemical fixation.

Some of the results from chemical analyses performed on samples taken during the first 2 weeks following the test included: 1) a 5- to 10-percent increase in volume of treated soil; 2) the potential long-term durability, low permeability and porosity, and high integrity of the solidified material; and 3) the probable immobilization of PCBs and heavy metals.²⁹ Although the reduction of volatile organic compounds was shown to occur, data limitations prohibited EPA from confirming the extent to which the IWT process immobilized these chemicals in the solidified soil. As a consequence, EPA considered

the results of the evaluation inconclusive,³⁰ stating that “since very limited bench-scale studies have been performed, it is recommended that treatability studies—site specific leaching, permeability, and physical tests—be performed on each specific site to be treated . . . whether low or high in organic content.”^{31 32}

More successful data have been gathered in the Netherlands from bench-scale tests of soil and sludge containing heavy metals, pesticides, and other organic compounds, such as pentachlorophenol.³³ Results obtained from bench-scale tests demonstrated that the maximum concentration of dioxin³⁴ detectable after treatment with the IWT process was 10.4 parts per trillion (ppt). Tetrachlorodibenzo-p-dioxin, the same dioxin species of concern at Times Beach, was found at only the 3.0-ppt level.³⁵

More recently, several studies of the IWT process conducted by both IWT and EPA have provided more optimistic results. IWT researchers, for example, have conducted various studies to prove that their fixation process bonds or destroys the organic contaminants present in waste. Results of these studies, however, have not been incorporated into the EPA demonstration process.³⁶ Despite the additional research required, EPA estimates that the IWT process has the potential to “meet many of the current or potential regulations for both organics and metals [particularly] where reductions in the contaminant concentration in the wastes are [required to be] measured.”³⁷

²⁶Newton, *op. cit.*, footnote 8, p. 2.

²⁷U.S. Environmental Protection Agency, *Op. Cit.*, footnote 7, pp. 34-35.

²⁸Newton, *op. cit.*, footnote 8, p. 9.

²⁹U.S. Environmental Protection Agency, *op. cit.*, footnote 7, pp. v, 2, 3, 9.

³⁰*Ibid.*, pp. 12-13.

³¹U.S. Environmental Protection Agency, *op. cit.*, footnote 7, pp. 2, 10.

³²According to a company official, the EPA conclusion is considered inadequate because: 1) EPA failed to apply the type of chemical analysis that would identify the extent and relevance of chemical bonding that occurs; 2) the SITE evaluation team lacked experts on organic/inorganic chemistry, clay chemistry, and physics; and 3) EPA failed to test whether freezing temperatures affected the ability of the additive to prevent leaching of chemicals (only physical structure was tested). Sources: Jeffrey P. Newton, President, International Waste Technologies, personal communication, Apr. 19, 1991; and U.S. Environmental Protection Agency, *op. cit.*, footnote 7, pp. 46-48.

³³Newton, *op. cit.*, footnote 8, p. 16.

³⁴heptachlorodibenzo-p-dioxin

³⁵Jeffrey P. Newton, President, International Waste Technologies, personal communication, Apr. 5>19910

³⁶U.S. Environmental Protection Agency, *op. cit.*, footnote 7, p. 13.

³⁷U.S. Environmental Protection Agency, Office of Research and Development, *op. cit.*, footnote 7, p. 13; U.S. Environmental protection Agency, Office of Research and Development Risk Reduction Engineering Laboratory, *Technology Demonstration Summary. International Waste Technologies/Geo-Con In Situ Stabilization/Solidification: Update Report*, EPA/540/S5-89/004a (Cincinnati, OH: January 1991).

UNDERGROUND MINE STORAGE

The use of underground mines as a method for storing hazardous waste is more common in Europe than in the United States. In Germany, for example, the increasing unavailability of storage capacity has prompted the storage of highly contaminated dioxin waste in underground mines. With the exception of packaging and labeling, this waste undergoes no special pretreatment. According to reports, efforts by the public and private sectors are focused primarily on searching for ways in which to store other dioxin-containing wastes such as fly ash and dust.³⁸

Unlike Europe, research and evaluation efforts in the United States on underground mine storage of dioxin-contaminated materials are limited. One research project was conducted in 1985 under the auspices of the Missouri Department of Natural Resources, EPA Region VII, and the University of Missouri School of Mines.

The main purpose of the Missouri study was to evaluate the feasibility of shallow underground mines as repository sites for soil originating from cleanup activities at some of the 44 dioxin-contaminated sites in the State. In its scope, the study covered 29 existing mines on the basis of dryness, structural stability, potential size, location, accessibility, packaging devices,³⁹ and costs. At its culmination, the project showed that shallow underground limestone and dolomite mines are most suitable for storing dioxin-containing soil, followed by sandstone, lead-zinc, iron, and coal mines.⁴⁰

Another conclusion of the study was that the costs of developing a dioxin repository are affected significantly by the type of container (steel vault, steel drum, woven polypropylene sacks), as well as

the packaging arrangement selected. With regard to capital costs, researchers estimated that costs of handling⁴¹ and storing dioxin-contaminated soil at existing underground mines were lower (\$225 to \$275) than those of excavating, bagging, and temporarily storing soil from three Missouri sites in steel-sided storage structures (\$754 to \$1,008).⁴²

After the Missouri study, researchers began to assess the feasibility of digging new underground depots to store contaminated soil.⁴³ Constructing new mines instead of using existing ones is being considered because storage costs may be reduced through eliminating the expense of rehabilitating existing, inactive mines. In addition, efforts to identify and evaluate permitting, packaging, monitoring, and transportation issues are planned.⁴⁴

ABOVEGROUND, ELEVATED STORAGE BUILDINGS

Aboveground, elevated storage buildings are large, permanent buildings constructed of prestressed concrete in which dioxin-contaminated materials might be stored temporarily in drums or containers. Although none has been constructed to date, aboveground storage proponents claim that once built, these facilities would reduce the cost of shipping contaminated materials overlong distances for treatment; reduce potential of groundwater contamination from landfills due to leaching of certain toxic components of the materials stored; and reduce potential air contamination by volatile emissions. According to proponents, another significant advantage of this approach is that it would facilitate subfloor, walk-through inspections because the drums will be stacked about 10 feet above the floor (see figure 4-3). In addition, this type of storage facility

³⁸Harmut S. Fuhr and J. Paul E. des Rosiers, "Methods of Degradation Destruction, Detoxification, and Disposal of Dioxins and Related Compounds," *Pilot Study on International Information Exchange and Related Compounds* (North Atlantic Treaty Organization, Committee on the Challenges of Modern Society, report No. 174, August 1988), p. 21.

³⁹Among the packaging options assessed were rectangular steel vaults, steel drums, and woven polypropylene sacks. The last type of containment, also called "supersacks," was the least expensive and had the largest storage capacity.

@des Rosiers, op. cit., footnote 19, pp. 124-125.

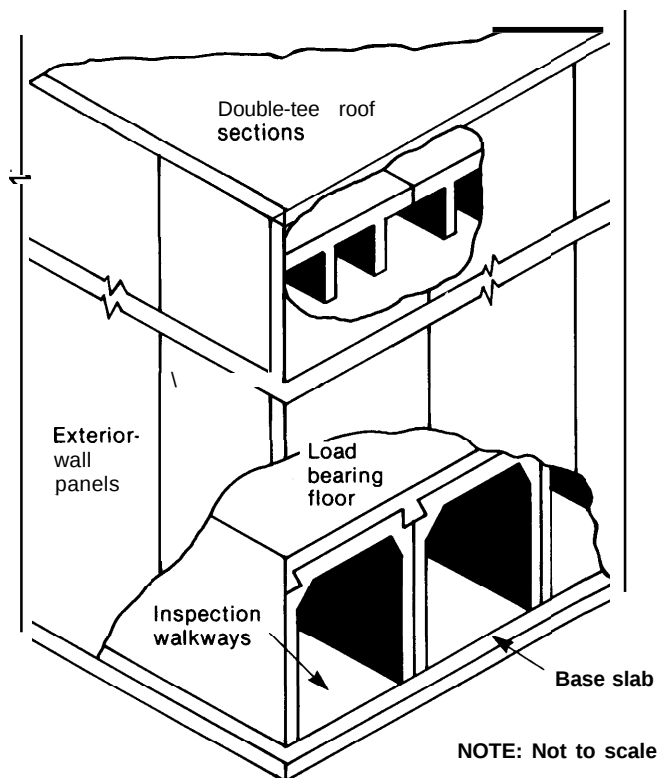
⁴¹Handling costs were found to represent about one-third of the overall costs.

⁴²des Rosiers, op. cit., footnote 19, p. 126.

⁴³Fuhr and des Rosiers, op. cit., footnote 38, pp. 21-22.

⁴⁴des Rosiers, op. cit., footnote 19, p. 126.

Figure 4-3—Example of Proposed Design for Aboveground Storage Facility



SOURCE: James V. Walters, University of Alabama, "Use of Elevated, Concrete Buildings for Sanitary Landfills, Hazardous-Waste Landfill, Monofill, and Cogenerator Facilities," *Journal of Resource Management & Technology*, vol. 17, No. 2, April 1989.

would allow time for the development of better technologies for treating contaminated soil.⁴⁵

Although aboveground storage is considered a viable alternative in hazardous waste management, particularly for long-term storage of waste or residues of waste treatment, only the New Jersey Hazardous Waste Facility Siting Commission has attempted to evaluate this system.

In May 1987, the Commission issued a report of its investigation on the technical, managerial, and regulatory experience of nine selected European nations with aboveground storage. In the report, the Commission calls for aboveground storage to be considered as a feasible alternative solution to the State's "residues management" problem because it may help to:

1. mitigate the decreasing storage capacity resulting from the promulgation of regulations barring hazardous waste disposal on land;
2. ease the capacity shortage created by the recent increase in the number of landfill closures; and
3. allow additional time for replacing current treatment, storage, and disposal facilities with newer, environmentally sound ones.⁴⁶

In November 1989, the Commission issued a report detailing design and operating criteria for above-ground storage buildings.⁴⁷ At this time, the Commission is considering design and construction plans for four different facilities in New Jersey.⁴⁸

⁴⁵James v. Walters, University of Alabama, personal communication, June 28, 1991; J.V. Walter, "Use of Elevated, Concrete Buildings for Sanitary Landfills, Hazardous-Waste Landfill, Monofill, and Cogenerator Facilities," *Journal of Resource Management & Technology*, vol. 17, No. 2, April 1989, pp. 124-130; J.V. Walters et al., "Elevated, Concrete Buildings for Long-Term Management of Hazardous Wastes," *Environmental Progress*, vol. 7, No. 4, November 1988, pp. 224-229.

⁴⁶Design Criteria Task Force, *Design Criteria for Above Grade Land Emplacement Facility*, report prepared for the New Jersey Hazardous Waste Facility Siting Commission, November 1989.

⁴⁷B.W. Plasecki and D.W. Ditz, American Hazardous Control Group, *Above Ground Land Emplacements for pretreated Hazardous Waste: The European Experience*, submitted to the New Jersey Hazardous Waste Facility Siting Commission, contract No. 491 O-1 OO-237030-50-NM-758; project activity No. 758, May 1987.

⁴⁸Susan Boyle, Executive Director, New Jersey Hazardous Waste Facility Siting Commission, personal communication, July 3, 1991.