Overview

Stabilization and solidification have been used for two to three decades as final treatment steps prior to land disposal of radioactive and chemically hazardous wastes. These technologies are also playing an increasingly important role for on-site or in-situ treatment and remediation of waste lagoons or contaminated soils. *Stabilization* refers to those aspects of the technology which result in rendering a waste less toxic through fixation of the contaminants that contain and/or by providing a stable chemical environment. *Solidification* is related to those operations which improve the physical and handling characteristics of the waste.

This Special Technical Publication contains 33 peer-reviewed papers out of 62 that were presented at the 4th International Hazardous Waste Symposium on Environmental Aspects of Stabilization/Solidification of Hazardous and Radioactive Wastes, held in Atlanta, Georgia, 3–6 May 1987. The symposium was sponsored by ASTM Committee D-34 on Waste Disposal, with Environment Canada and the Alberta Environmental Centre representing the chemically hazardous waste management field, and the U.S. Department of Energy and the Oak Ridge National Laboratory (ORNL) representing the radioactive waste management field. Although the two scientific communities, working on chemically hazardous or low-level radioactive waste, are faced with similar problems and basically work with the same technology, the symposium represented the first forum for technology exchange. This first encounter was an occasion to understand the gap that separate two groups that use a different vocabulary and are subject to markedly different regulations. The later fact has resulted in the creation of a new category of wastes in the United States, "mixed wastes" that fall under both the Nuclear Regulatory Commission radioactive wastes and the Environmental Protection Agency hazardous wastes regulations, which are not always compatible. Following the symposium, the contacts have intensified between the two communities, which should certainly result in a better and wider use of the technology.

Land disposal of waste should be avoided when possible. Waste reduction, recycle, and reuse (for nonradioactive wastes) are obviously superior alternatives. There are, however, instances where the physical nature of the waste, and the type and concentration of contaminants that it contains do not technically or economically allow avoidance of the land disposal option. In these instances, the waste should be treated to the maximum extent possible, to reduce its volume. Solidification of large quantities of contaminated water, although possible, should be avoided. When properly managed, land disposal after stabilization and solidification will ensure long-term containment of the waste constituents.

A wide spectrum of wastes can be stabilized and solidified prior to land disposal. These include radioactive and/or chemically hazardous wastes such as incinerator ash and other combustion ashes, sludges, and filter cakes from physical and chemical wastewater treatment operations, contaminated soils, foundry sands, spent catalysts, tank bottoms, mine tailings, and dredged sediments. These wastes may contains inorganic contaminants (for example, lead, mercury, cadmium) and a wide variety of organic contaminants. Although, stabilization, solidification, and land disposal are normally not considered a prime alternative for organic wastes, organic contaminants are often associated in small quantities with inorganic matrices (for example, PCB contaminated soils). There is a fundamental difference between radioactive and chemically toxic contaminants. While the hazards associated with some of the former decrease with time as a result of decay and eventually disappear, chemically hazardous contaminants remain so for ever. This fact stresses the need for effective long term containment.

The stabilization/solidification technology involves mixing a waste with additives to chemically stabilize it and physically contain it, producing a waste form suitable for shallow land burial. Stabilization and solidification processes are often classified based on the principal additives used to obtain a solid matrix. Various systems based on inorganic and organic additives are listed below:

Inorganic-based Systems	*Organic-based Systems*
portland cement	bitumen
soluble silicates-cement	urea formaldehyde
pozzolan-lime	polybutadiene
pozzolan-cement	polyester
clay-cement	epoxy
gypsum	polyethylene

Technologies based on vitrification and disposal in deep geological formations have mostly been considered for high-level radioactive waste and are beyond the scope of this publication.

Inorganic-based systems all use some kind of hydraulic cement that allows the waste form to develop sufficient strength to be self-supporting in a landfill. Portland cement is most frequently used. Pozzolanic cements used in stabilization and solidification are often themselves waste materials such as power plant fly ash, cement kiln dust, and ground blast furnace slag. Cement-based processes are well suited to the treatment of aqueous wastes since cement needs water for hardening. A cement-based waste form is a porous matrix whose hydraulic conductivity is a function of the pore structure and the amount of water originally present in the waste. The leaching of a contaminant thus depends on whether it remains in solution in the pore system or is immobilized through chemical reaction. Cement-based processes create an alkaline environment suitable to the containment of several toxic metals. The additives, which are often themselves waste materials are inexpensive and can be blended with the waste using simple equipment. Cement-based processes have widely been used commercially for chemically hazardous wastes and low-level radioactive wastes.

Organic-based processes consist in encapsulating waste elements in an impervious matrix that is placed in a container to maintain dimensional stability in the landfill. Organic-based additives are normally hydrophobic. When used with aqueous waste streams, water is either evaporated in thermosetting processes (for example, bitumen) or encapsulated within the polymer matrix in catalyst-based processes. Organic-based processes normally show very low leaching of contaminants since the matrices are impervious. However, there is usually no reaction between the waste constituents and the polymer. Since hazardous constituents are not destroyed or insolubilized, the long-term stability of the waste form depends entirely on its physical integrity in the disposal environment. Organic-based processes are energy-intensive, requiring high cost additives and sophisiticated blending equipment. Their use has been practically limited to special types of high-hazard, low-volume radioactive wastes.

Most of the attention of the scientific community with regard to the stabilization and solidification technology has focused on understanding and predicting long-term containment. The most likely exposure route is water, and leaching tests play a central role in evaluating waste forms. A well designed land disposal operation often contains multiple barriers between the waste and the environment. Liners, either low permeability soils or polymeric membranes, are used for macrocontainment. Wastes may also be placed in engineered containers such as concrete tanks or jacketed drums. A waste form, either cement or organic based, is therefore the last element in a line of defense to prevent release of contaminants to the environment. Long-term containment studies can be broadly categorised in two groups, leaching studies and durabilities studies. Leaching is the study of the transfer of contaminants from the waste form to water. Durability refers to the ability of the waste form to resist wear and remain intact for a long period of time.

The content of this Special Technical Publication is well balanced. Fourteen papers deal with radioactive wastes, 16 with chemically hazardous wastes, and 3 with mixed wastes. The papers were grouped in four chapters to deal with: (1) Processes, (2) Regulatory Aspects and Testing Methods, (3) Laboratory Evaluation, and (4) Large-scale Evaluation or Demonstration.

Processes

There are numerous research and development efforts being spent in formulating stabilization and solidification processes. Endless variations of basic processes based on cement or pozzolan have been developed to address specific containment problems. Most of that information is however proprietary and was discussed more during coffee breaks than within formal presentations at the symposium! Of the seven papers included in this section, two are cement-based (an under-representation), four are organic-based (an over-representation) and one is about drum jacketing. This latter paper is borderline between the topic of this publication, micro-containment, and macrocontainment through engineered barriers.

Regulatory Aspects and Testing Methods

Regulations pertaining to the land disposal of stabilized and solidified wastes are still being developed. The radioactive waste community is ahead in this area as reflected by two papers describing the rules in the United States and in Italy. The lack of regulations in the chemically hazardous waste field has often been blamed for the relatively small role that the technology has played overall in the management of hazardous waste.

Testing methods for stabilized and solidified wastes are needed at different levels of control. At the *research level,* a wide variety of testing methods may be used to gain an understanding of the morphological, chemical, and engineering properties of waste forms. Several papers in this section describe the development or illustrate the utilization of testing methods used to provide fundamental information. The next level is the *regulatory level* where standard testing methods are used in conjunction with set performance criteria to determine the suitability of a technology applied to a specific waste stream in a given disposal scenario. Several testing methods that would meet the conditions to be used as regulatory tools are discussed in this section. The following level is the *treatability study level* where simple and rapid testing methods are needed to select an optimal formulation that would meet regulatory levels (without having to run the regulatory test on every formulation). The last level is the very important *Quality Assurance/Quality Control level* where tests are needed to verify that the performance obtained in the laboratory is reproduced under large-scale or field conditions. The two last levels are addressed in two papers but would certainly deserve more attention in the future.

Laboratory Evaluation

The seven papers included in this section present process development or application work done at bench scale, which involves the selection of specific additives to optimize containment or the investigation of the mechanisms of containment or leaching.

Large-scale Evaluation or Demonstration

It is important to remember that laboratory leaching tests only partially evaluate a waste containment system. Their results cannot be directly interpreted in terms of field leachate concentration. As a result, large-scale evaluation or demonstration studies are an important part in the determination of the environmental suitability of waste forms. The eight papers in this section were all contributed by researchers from the radioactive waste field, a clear indication of the leading role that they are playing in putting stabilization and solidification to use.

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