

STABILIZATION AND
SOLIDIFICATION OF

Hazardous, Radioactive,

AND

Mixed Wastes

Gilliam/Wiles,
editors



STP 1123

SECOND
VOLUME

STP 1123

***Stabilization and Solidification of
Hazardous, Radioactive, and
Mixed Wastes, 2nd Volume***

T. Michael Gilliam and Carlton C. Wiles

ASTM Publication Code Number (PCN)
04-011230-56



ASTM
1916 Race Street
Philadelphia, PA 19103

Library of Congress Cataloging in Publication Data

ASTM Publication Code Number (PCN) 04-011230-56

ISBN 0-8031-1443-5

ISSN 1059-423X

Copyright © 1992 AMERICAN SOCIETY FOR TESTING AND MATERIALS, Philadelphia, PA. Prior edition copyrighted 1989 by the American Society for Testing and Materials. All rights reserved. This material may not be reproduced or copied, in whole or in part, in any printed, mechanical, electronic, film, or other distribution and storage media, without the written consent of the publisher.

Photocopy Rights

Authorization to photocopy items for internal or personal use, or the internal or personal use of specific clients, is granted by the AMERICAN SOCIETY FOR TESTING AND MATERIALS for users registered with the Copyright Clearance Center (CCC) Transactional Reporting Service, provided that the base fee of \$2.50 per copy, plus \$0.50 per page is paid directly to CCC, 27 Congress St., Salem, MA 01970, (508) 774-3350. For those organizations that have been granted a photocopy license by CCC, a separate system of payment has been arranged. The fee code for users of the Transactional Reporting Service is 0-8031-1443-5/91 \$2.50 + .50.

Peer Review Policy

Each paper published in this volume was evaluated by three peer reviewers. The authors addressed all of the reviewers' comments to the satisfaction of both the technical editor(s) and the ASTM Committee on Publications.

The quality of the papers in this publication reflects not only the obvious efforts of the authors and the technical editor(s), but also the work of these peer reviewers. The ASTM Committee on Publications acknowledges with appreciation their dedication and contribution to time and effort on behalf of ASTM.

Printed in Baltimore, MD
January 1992

Foreword

This publication, *Stabilization and Solidification of Hazardous, Radioactive, and Mixed Wastes, 2nd Volume*, contains papers presented at the Second International Symposium on Stabilization/Solidification of Hazardous, Radioactive, and Mixed Wastes, which was held in Williamsburg, Virginia, 29 May to 1 June 1990. The symposium was sponsored by ASTM Committee D-34 on Waste Disposal, Oak Ridge National Laboratory, U.S. Environmental Protection Agency, Hazardous Substance Management Research Center of the New Jersey Institute of Technology, Environment Canada, and Alberta Environmental Centre. T. Michael Gilliam, Oak Ridge National Laboratory, was symposium chairman. The editors of this book, T. Michael Gilliam and Carlton C. Wiles, wish to express their appreciation to the symposium attendees, authors, and ASTM staff who have contributed to this publication. A special note of gratitude is due to those individuals who served as peer reviewers for the papers presented in this publication.

Contents

Overview

ix

REGULATORY AND TECHNICAL GUIDANCE

- Low-Level Radioactive Waste Disposal in the United States—**
RICHARD L BANGART AND MICHAEL TOKAR 3
- Issues Related to the Public and Regulatory Acceptance of Performance Standards
for Wastes Remaining on Hazardous Waste Sites—**JOHN J BARICH, III AND
B J MASON 12
- Solidification/Stabilization: Is It Always Appropriate?—**CARLTON C WILES AND
EDWIN BARTH 18
- Guidelines for Evaluation of the Permanence of a Stabilization/Solidification
Technology—**RENGARAJAN SOUNDARARAJAN 33

SPECIALTY WASTES ORGANICS, ASHES, AND RESINS

- A Critical Review of the Effectiveness of Stabilization and Solidification of
Hazardous Organic Wastes—**ROBERT E BROWN, BIPENDER S JINDAL, AND
JOSEPH D BULZAN 43
- Stabilization/Solidification of Wastes Containing Volatile Organic Compounds in
Commercial Cementitious Waste Forms—**ROGER D SPENCE,
T MICHAEL GILLIAM, IVAN L MORGAN, AND STEVEN C. OSBORNE 61
- Solidification and Stabilization of Phenol and Chlorinated Phenol Contaminated
Soils—**NANCY J SELL, MARK A. REVALL, WILLIAM BENTLEY, AND
THOMAS H McINTOSH 73
- Incorporation of Radioactive Ashes into Ceramic-Clay Matrices—**A S ALOY,
A S VISHNEVSKII, T I KOLYCHEVA, B A KUZNETSOV, AND
E A. SHASHUKOV 86
- Fixation of Residues from Special Hazardous Waste Incinerators for Shallow Land
Disposal—**DORIS ASSMANN AND BERTHOLD-GUNTER BRODDA 90

Chemical Fixation of Flue Gas Desulfurization Sludges and Fly Ash— PAUL L BISHOP, TIM C KEENER, DAVID C DUSING, RUNZHI GONG, AND CHONG-LE LI	103
Evaluation of the Impact of Ocean Disposal of Stabilized/Solidified Municipal Solid Waste Incinerator Ash on Marine Sediments— NANCY E KINNER, DIANA B DURLING, W BERRY LYONS, DAVID L GRESS, AND M ROBIN COLLINS	119
Performance Testing of Grout-Based Waste Forms for the Solidification of Anion Exchange Resins— IVAN L MORGAN AND WILLIAM D BOSTICK	133

LABORATORY-SCALE LEACHABILITY STUDIES

Determination of Leaching Characteristics of Waste Materials Leading to Environmental Product Certification— GERARD J DE GROOT AND HANS A. VAN DER SLOOT	149
Release of Toxic Elements from Solidified Wastes: A Mathematical Model— FRANCO MEDICI, CARLO MERLI, GIANCARLO SCOCCIA, AND ROBERTO VOLPE	171
Leach Studies: Influence of Various Parameters on the Leachability of Cesium from Cemented BWR Evaporator Concentrates— GIORGIO DE ANGELIS, ANTONIA MARCHETTI, AND STEPHANIA BALZAMO	182
Effects of Selected Waste Constituents on Solidified/Stabilized Waste Leachability— LARRY W JONES, R MARK BRICKA, AND M JOHN CULLINANE, JR	193
Short-Term Leaching Behavior of Co-60, Sr-85, and Cs-137 from Cemented Ion- Exchange Resin Waste Forms— JAE-OWAN LEE, KYONG-WON HAN, AND LEO P BUCKLEY	204
Effect of Hydrating Water on the Physical Characteristics and the Diffusion Release of Cesium Nitrate Immobilized in Cement— EDMONDO ZAMORANI AND GIORGIO SERRINI	217
A Model of the Attack of Pure Water or Undersaturated Lime Solutions on Cement— MICHEL BUIL, ELIANE REVERTEGAT, AND JEAN OLIVER	227
Long-Term Leaching Performance for Commercially Stabilized Waste— KIMBERLY J PERRY, NEIL E. PRANGE, AND WILLIAM F GARVEY	242

LABORATORY-SCALE PROCESS DEVELOPMENT

Application of Radioactive Waste Solidification Methods to Hazardous Wastes in Italy— ALDO DONATO AND GIUSEPPE A RICCI	255
---	-----

Stabilization and In Situ Management of Radioactive Contaminated Sediments of the Port Hope Harbor —GEORGE M DOLINAR, R W DOUG KILLEY, AND KEN E PHILIPOSE	266
Mixture Design Optimization Considering Three Disposal Options for Solidified Heavy Metal Sludges —HANG-SIK SHIN, JONG-OH KIM, JA-KONG KOO, AND EUNG-BAI SHIN	283
Solidification of Dried Borate Waste with Polyester —HWAN-YOUNG KIM, KI-HONG KIM, HUN-HWEE PARK, AND IN-SUK SUH	297
Laboratory Evaluation of Stabilization/Solidification Technology for Reducing the Mobility of Heavy Metals in New Bedford Harbor Superfund Site Sediment —TOMMY E MYERS AND MARK E ZAPPI	304
Cement Conditioning of Waste Materials and Polluted Soil Using the GEODUR Process —KNUD BRODERSEN, OLE HJELMAR, AND SVEND MORTENSEN	320
Cementation of Borate Waste by Adding Slaked Lime —JOON-HYUNG KIM, HWAN-YOUNG KIM, HUN-HWEE PARK, AND IN-SUK SUH	338
The Development of Cement Formulations for Radioactive Waste Encapsulation —DAVID J LEE AND ANDREW FENTON	348

TEST METHOD DEVELOPMENT

Generalized Acid Neutralization Capacity Test —JERRY ISENBURG AND MICHAEL MOORE	361
Methods of Evaluating Explosive Reactivity of Explosive-Contaminated Solid Waste Substances —T S BAJPAYEE AND RICHARD J MAINIERO	378
An Assessment of Short-Term Penetration Testing as an Indicator of Strength Development in Solidified/Stabilized Hazardous Waste —M JOHN CULLINANE, JR AND LARRY W JONES	385
Development of an In-Line Grout Meter for Improved Quality Control —GUILLERMO D DEL CUL AND T MICHAEL GILLIAM	394

LARGE-SCALE EVALUATION OR DEMONSTRATION

Summary of Solidification/Stabilization SITE Demonstrations at Uncontrolled Hazardous Waste Sites —EDWIN F. BARTH	409
Field Demonstration of In Situ Grouting of Radioactive Solid Waste Burial Trenches with Polyacrylamide —BRIAN P SPALDING AND THOMAS A FONTAINE	415

Stabilization/Solidification of Metal-Contaminated Soils: Two Case Histories— JAMES H KLEPPE, MARK T. OTTEN, AND JOHN T FINN	426
Dynamic Compaction of Nuclear Waste Deposits— ROBERT G LUKAS AND CLIFF SCHEXNAYDER	440
Contributions of Lysimeter Data to the Development of Site Specific Performance Assessment Plans— ROBERT D ROGERS, JOHN W McCONNELL, JR., JULIE D JASTROW, AND DIANA S WICKLIFF	448
Laboratory Treatment and Field Demonstration Lessons Learned from a Waste Stabilization Project— JEFFREY L MEANS, JEFFERY C HEATH, AND WILLIAM J. McLAUGHLIN	466
Performance Appraisal of Full-Size Radioactive Waste Packages— J C NOMINE AND A BILLON	479
Indexes	495

Overview

Stabilization and solidification (S/S) technologies have been used for decades as a final treatment step prior to the disposal of both radioactive and chemically hazardous wastes. Stabilization refers to the alteration of waste contaminants to a more chemically stable form (i.e., a form which results in a greater difficulty of contaminant release to the environment), thereby resulting in a more environmentally acceptable waste form. Solidification refers to the physical alteration of the waste to restrict water release from or access to the waste and thereby resulting in a more environmentally acceptable waste form. Typically, stabilization processes also involve some form of physical solidification.

This Special Technical Publication contains 39 peer-reviewed papers out of the 70 that were presented at the Second International Symposium on Stabilization/Solidification of Hazardous, Radioactive, and Mixed Wastes, held in Williamsburg, Virginia, 29 May-1 June 1990. This symposium was sponsored by ASTM Committee D-34 on Waste Disposal, Oak Ridge National Laboratory, Risk Reduction Engineering Laboratory, Office of Research and Development of the U.S. Environmental Protection Agency (EPA), Hazardous Substance Management Research Center of the New Jersey Institute of Technology, Environment Canada, and Alberta Environmental Centre. Cooperating organizations include the Commission of the European Communities (CEC), Brussels, Belgium, ENEA (Comitato Nazionale per la Ricerca e per lo Sviluppo dell'Energia Nucleare e delle Energie Alternative), Rome, Italy, Netherlands Energy Research Foundation (ECN), Petten, The Netherlands, Imperial College of Science, Technology & Medicine, University of London, London, England; VKI (Water Quality Institute), Horsholm, Denmark, Studiecentrum voor Kernenergie/Centre d'etude de l'Energie Nucleaire (SCK/CEN), Mol, Belgium; Korea Advanced Institute of Science and Technology (KAIST), Seoul, Korea, KAERI (Korea Atomic Energy Research Institute, Chung-Nam, Korea, Agence Nationale pour la Recuperation et l'Elimination des Dechets-Les Transformeurs, Angers, France; and RISO National Laboratory, Roskilde, Denmark.

This symposium series (scheduled once approximately every three years) provides a forum for technical exchange between researchers working with S/S technologies from both the low-level radioactive and chemically hazardous waste communities. Although the two scientific communities are faced with similar problems and basically work with the same technologies, this symposium series presents a unique forum for technical exchange between the two communities. This meeting is the second in the series. Papers from the first meeting in the series were published in STP 1033, *Environmental Aspects of Stabilization and Solidification of Hazardous and Radioactive Wastes*.

Land disposal restrictions are becoming ever increasingly stringent, driven by technical, regulatory, and political considerations. To the largest extent practicable, alternatives to land disposal are desirable, such as waste minimization, recycling, and destruction (e.g., incineration). In many instances, however, these alternatives are unrealistic due to the physical nature or location of the waste, the type and concentration of contaminants that it contains, or technical and economic issues. In such cases, S/S technology is a viable technical option which has historically proven to be cost effective.

A wide variety of both radioactive and chemically hazardous wastes are amenable to S/S. These include liquids, sludges, filter cakes, contaminated soils, and ash. S/S technologies are

often used with chemically hazardous wastes contaminated with metals (e.g., lead, nickel, chromium) and are routinely used with low-level radioactive wastes of all types. Clearly, S/S is not the preferred technology for organic-rich wastes, but research is increasingly focusing on its application to wastes containing trace levels of organic contaminants.

S/S technologies are often classified on the basis of the principal additives used to obtain a solid matrix. Various systems based on organic and inorganic 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

The specific technology used is based on several factors including volume increase, performance requirements, economics, logistic constraints, and material availability.

Inorganic-based systems may involve both stabilization and solidification. They generally utilize a hydraulic binder which reacts with water to form a solid product. Portland cement is the most commonly used binder. Cement-based systems are widely used due to the availability of raw materials, compatibility with existing process equipment, and adaptability to a variety of process configurations and waste-form performance requirements. Pure cement systems are becoming increasingly rare. Additives such as fly ash, granulated blast furnace slag, and specialty clays are used to improve waste-form performance and to minimize the cost. Compared with a pure cement system, these additives can reduce the resulting volume increase, reduce porosity (and, thus, reduce leachability), and increase compressive strength.

Organic-based systems consist of encapsulating the waste in a matrix that is essentially impervious to water. As such, they are designated as solidification processes. Many of these systems require water removal from the waste prior to solidification and thus result in an overall volume decrease. Products from these systems require a container to provide the necessary structural integrity to support overburden pressure. Use of such systems has been limited to special types of high-hazard, relatively low-volume, radioactive wastes due to the increased costs generally associated with these systems.

The scientific community has been focusing attention on understanding and predicting the long-term containment prospects of waste treated with this technology. Consequently, the majority of papers presented in this publication address to some degree one or both of the two principal issues associated with long-term containment, leachability and durability. Leachability refers to the release of contaminants from the waste form upon exposure to an aqueous media. Durability refers to the ability of the waste form to maintain its structural integrity upon exposure to expected environmental conditions.

Attendees from 14 countries participated in this meeting, and the papers presented in this publication represent a cross section of research activities being conducted in this field worldwide. The papers are grouped into six sections to deal with (1) Regulatory and Technical Guidance; (2) Specialty Wastes: Organics, Ashes, and Resins; (3) Laboratory-Scale Leachability Studies; (4) Laboratory-Scale Process Development; (5) Test Method Development; and (6) Large-Scale Evaluation or Demonstration.

Significant overlap among the papers is evident. For example, papers grouped under Laboratory-Scale Process Development may well contain information pertinent to Laboratory-

Scale Leachability Studies This is to be expected as the papers are grouped primarily based on the application of the data and conclusions as presented by the authors rather than on the data themselves. Moreover, the papers were purposely not grouped according to waste category (hazardous, radioactive, and mixed). The purpose of this meeting was to provide information exchange between the various technical communities. The presentations clearly showed that materials, processes, performance requirements, methods of experimentation, and subsequent data analyses were, for the most part, waste-category independent. Thus, only by reading papers from all represented technical communities can one get a true understanding of what this technology can and cannot do.

Regulatory and Technical Guidance

When contemplating the use of S/S technology for a particular application, the first questions asked are: What are the pertinent regulatory requirements? Has this technology been used successfully on similar wastes? What test methods can be used to assess the effectiveness of this technology? The four papers presented in this section deal directly with these questions. The first two papers address pertinent regulatory issues, the third addresses previous successes and failures; and the fourth addresses available examination techniques.

Specialty Wastes: Organics, Ashes, and Resins

S/S technology is used routinely in the nuclear industry for the treatment of low-level radioactive wastes. In addition, the EPA has specified S/S technology as the best demonstrated and available technology for a variety of wastes containing metals, such as cadmium, chromium, and lead. Clearly, one of the roles of the scientific community is to define the limits of existing technology and expand those limits where appropriate. Indeed, the majority of the papers presented in this publication could be viewed as contributing to this endeavor. Eight papers are presented in this section which directly address the application of this technology to three waste types of particular interest during the meeting: organics, combustion residues (e.g., ashes), and resins. The first three papers deal with the issue of organic-containing wastes and range from a review of existing literature to on-going experimental studies. Four of the papers deal with combustion residues such as incinerator ash, fly ash, and/or desulfurization sludges. One paper deals with anion exchange resins.

Laboratory-Scale Leachability Studies

Understanding the mechanisms involved in the leaching of a waste form is crucial to predicting its long-term performance in the environment. At present, the prediction of long-term behavior must rely on leaching studies and their associated leach-model development due to (1) a lack of understanding of the chemistry and morphology of the waste form, resulting in a limited ability to quantitatively predict its long-term performance and (2) both the lack of and difficulty in interpreting field-scale leach data, resulting in limited verification of laboratory-scale leach studies and derived models. Eight papers are presented in this section which deal with the development of leach models and/or determining parameters that affect waste-form leachability. Collectively, these papers indicate the similarity between the performance of waste forms containing hazardous and radioactive wastes. The editors believe that this subject more than any other shows the benefits and need for information exchange between the technical communities.

Laboratory-Scale Process Development

Numerous research and development efforts are being expended in formulating stabilization and solidification processes. The eight papers presented in this section provide an excellent cross section of these development efforts. The majority of the papers deal with cement-based systems (the most commonly used) and clearly show the benefits of the use of additives such as fly ash, granulated blast furnace slag, and slaked lime. Four of the papers address alternatives to the cement-based systems including compaction (a form of solidification), sodium silicates, polyesters, and urea formaldehyde.

Test Method Development

Test methods are useful tools in evaluating S/S technologies. Appropriate test methods have the potential to increase one's knowledge of the process or product, decrease the time needed to acquire this knowledge, or improve the product/process. The four papers presented in this section address all of these potential uses and range from laboratory-scale application to improved process control.

Large-Scale Evaluation or Demonstration

The papers presented in this publication are predominantly related to laboratory-scale studies, which is an accurate representation of the level of effort applied in the scientific community. Laboratory-scale studies are dominant for a variety of reasons including the ability to control variables of interest, which facilitates the determination of cause-and-effect relationships. It is this control which necessitates the need for large-scale evaluation or demonstration. Large-scale studies are needed to determine performance under less-controlled conditions that are inherent to field-scale operations, such as variability of the waste feed (both chemical and physical), variability in ability to control process parameters, and variability in environmental exposure conditions on the product. The seven papers presented in this section address a variety of S/S techniques ranging from dynamic compaction to in situ stabilization. Two of the papers provide case history studies which indicate the interrelationship between laboratory and full-scale studies. The first paper in this section provides a summary of demonstrations conducted under the EPA's Superfund Innovative Technology Evaluation Program and can serve as a guide to information available on this subject from other sources.

T. Michael Gilliam

Oak Ridge National Laboratory, Oak Ridge,
TN 37831-7273, symposium chairman and
editor

Carlton C. Wiles

Environmental Protection Agency, Cincinnati,
OH, editor

ISBN 0-8031-1443-5