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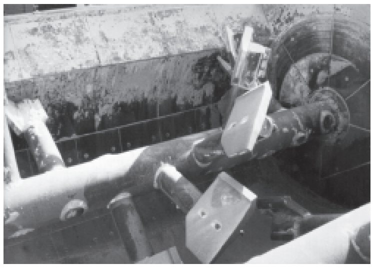
Solidification/Stabilization Resource Guide



SOLIDIFICATION/STABILIZATION RESOURCE GUIDE

U.S. Environmental Protection Agency
Office of Solid Waste and Emergency Response
Technology Innovation Office
Washington, D.C. 20460

April 1999

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FOREWORD

This Solidification/Stabilization Resource Guide is intended to inform site cleanup managers of recently-published materials such as field reports and guidance documents that address issues relevant to solidification/stabilization technologies. In addition to a short abstract for each of the resources listed, the guide includes a look-up table that allows the user to quickly scan the contents. Information on how to obtain a specific document also is included.

NOTICE

This document was prepared by the United States Environmental Protection Agency (EPA) under EPA Contract Number 68-W5-0055. Mention of trade names or commercial products does not constitute endorsement or recommendation for use.

This document is part of a series of technology resource guides prepared by the Technology Innovation Office. The series includes the following technology guides: the Bioremediation Resource Guide (EPA/542/B-93/004); the Ground-Water Treatment Technology Resource Guide (EPA/542/B-94/009); the Physical/Chemical Treatment Technology Resource Guide (EPA/542/B-94/008); the Soil Vapor Extraction Resource Guide (EPA/542/B-94/007); and the Soil Vapor Extraction Enhancement Technology Resource Guide (EPA/542/B-95/003). These and other technology-related documents are available over the Internet at the Hazardous Waste Clean-Up Information (CLU-IN) Web Site at *http://clu-in.org*.

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INTRODUCTION

EPA is committed to identifying the most effective and efficient means of addressing the thousands of hazardous waste sites in the United States. In addition, EPA seeks to ensure that decision-makers are aware of current information on the performance of remediation technologies, policies, and other sources of assistance. This Guide was prepared to help identify documents that can directly assist Federal and State site managers, contractors, and others responsible for the evaluation of technologies. This Guide was developed for those who are considering solidification/stabilization technologies for the remediation of RCRA, UST, and CERCLA sites.

This Guide has abstracts of 125 solidification/stabilization technology guidance and policy documents, overview/program documents, studies and demonstrations, workshops/conference proceedings, books, journal references, bibliographies, in situ solidification/stabilization resources, and other resource guides. A matrix is provided to allow easy screening of the abstracted references.

Documents listed in this Guide were found through a literature search conducted using several commercial and Federal databases including EPA's web site at http://www.epa.gov/, the National Technical Information Service (NTIS), and DIALOG One Search Databases. The selected references are not an exhaustive list of all available literature, but rather a representative sample of the available literature. Because of the inherent lag time between document publication and subsequent listing in electronic databases, there may be more recent references available than those included in the Guide. Most of the references in the Guide are of documents published between 1994 and 1998. The documents are available from sources such as EPA's National Service Center for Environmental Publications (NSCEP), NTIS, document delivery services, and a variety of libraries. Further, all documents listed in this Guide as having been prepared by the Technology Innovation Office are available over the Internet at *http://clu-in.org*. Information in this Guide does not represent an endorsement by EPA.

HOW TO USE THIS GUIDE

When using this Guide to identify resource information on solidification/stabilization technologies, you may wish to take the following steps:

1. Turn to the **Solidification/Stabilization Technology Resource Matrix** located on page 9. This matrix lists alphabetically by document type 125 solidification/stabilization technology-related documents, identifies the type of information provided by each document, and provides a document ordering number.
2. Select the document(s) that appear to fit your needs based on the information in the matrix.
3. Check the abstract identification number. This number refers to an abstract of the document.
4. Review the abstract that corresponds to the document in which you are interested to confirm that the document will fit your needs.
5. If the document appears to be appropriate, note the document number presented under the abstract. For example:

EPA Document Number: EPA/542/-B-95-003

6. Turn to the section entitled "How to Order Documents Listed in this Guide" on page 5 of this Guide and order your document using the directions provided.
7. When seeking information on technical assistance sources, turn to page 79 of this guide
8. If you would like to comment on this Guide or would like additional information, turn to page 85 of this Guide and follow the directions for mailing or faxing your comments/questions.

HOW TO ORDER DOCUMENTS LISTED IN THIS GUIDE

Documents listed in this Guide are available through a variety of sources. When ordering documents listed in the Solidification/Stabilization Technology **Abstracts** section of this Guide, use the number listed in the bar below the abstract. If using the Solidification/Stabilization Technology Resource **Matrix**, use the number listed below the document title. If multiple document ordering numbers are identified, select the appropriate number based on the directions below. EPA/530, EPA/540, EPA/600, and EPA/625 documents may be available through the Center for Environmental Research Information (CERI); EPA/540 and EPA/542 documents may be obtained through the National Service Center for Environmental Publications (NSCEP); and EPA/530 documents may be obtained from the RCRA Information Center (RIC). These document repositories provide in-stock documents free of charge, but document supplies may be limited. Documents obtained through the National Technical Information Service (NTIS) are available for a fee; therefore, prior to purchasing a document through NTIS, you may wish to review a copy at a technical or university library, or a public library that houses government documents. Out-of-stock documents may be ordered from NSCEP or may be purchased from NTIS. Several Portland Cement Association (PCA) publications also can be obtained by contacting PCA's Publications Order Processing Department.

Document Type	Document Source
Publication numbers with the following prefixes: AD DE PB PR (free of charge)	To send a request: National Technical Information Service (NTIS) U.S. Department of Commerce 5285 Port Royal Road Springfield, VA 22161 Sales Desk: 1-800-553-NTIS(6847) or (703) 605-6000 Operates Monday - Friday, 8:00 a.m. -8:00 p.m., Eastern Time Subscriptions: 1-800-363-2068 or (703) 605-6000 Operates Monday - Friday, 8:30 a.m. - 5:00 p.m., Eastern Time TOD: (703) 487-4639 Operates Monday - Friday, 8:30 a.m. - 5:00 p.m., Eastern Time To fax a request: (703) 605-6900 Available 24 hrs, 7 days a week. To verify receipt of fax, call (703) 605-6090 Operates Monday - Friday, 7:00 a.m. - 5:00 p.m., Eastern Time Email: orders@ntis.fedworld.gov http://www.ntis.gov/ordering.htm

HOW TO ORDER DOCUMENTS LISTED IN THIS GUIDE (CONT'D)

Document Type	Document Source
Publications with the following numbers: EPA/530 (limited collection) EPA/540 (limited collection) EPA/600 EPA/625	To send a request: Center for Environmental Research Information (CERI) Cincinnati, OH 45268 Sales Desk: (513) 569-7562 To fax a request: (513) 569-7566 Operates Monday - Friday, 8:00 a.m. - 4:30 p.m., Eastern Time ORD publications: http://www.epa.gov/docs/ORD ORD Technologies Transfer highlights: http://www.epa.gov/ttbnrmrl/ceri.htm Email: ord.ceri@epamail.epa.gov
Publications with the following numbers: EPA/540 EPA/542 A document title or number is needed to place an order with NSCEP. Some out-of-stock documents may be ordered from CERI or may be purchased from NTIS.	To send a request: U.S. Environmental Protection Agency National Service Center for Environmental Publications (NSCEP) P.O. Box 42419 Cincinnati, OH 45242-2419 Sales Desk: 1-800-490-9198, (513)-489-8190 To fax a request: (513) 489-8695 Operates Monday - Friday, 7:00 a.m. - 5:30 p.m., Eastern Time email: ncepi.mail@epamail.epa.gov http://www.epa.gov/ncepihom/ordering.htm
Publications with EPA/530 numbers	To send a request: U.S. Environmental Protection Agency RCRA Information Center (RIC) 401 M St., S.W. Mailcode: 5305 W Washington, DC 20460 Sales Desk: (703) 603-9230 Operates Monday - Friday, 9:00 a.m. - 4:00 a.m., Eastern Time To fax a request: (703)-603-9234 email: rcra-docket@epamail.epa.gov http://www.epa.gov/epaoswer/general/ricorder.htm
If you have difficulty finding a document or wish to obtain EPA/510 documents	RCRA/Superfund/EPCRA Hotline: (800) 424-9346, (703) 412-9810 TDD: (800) 553-7672, (703) 412-3323 Operates Monday-Friday, 9:00 a.m. - 6:00 p.m., Eastern Time
Publications prepared by PCA	To send a request: Order Processing Department P.O. Box 726 Skokie, IL 60076-0726 Request Desk: 1-800-868-6733 email: http://www.portcement.org

TECHNOLOGY SUMMARY

Solidification and stabilization are generic names applied to a wide range of discrete technologies that are closely related in that both use chemical and/or physical processes to reduce potential adverse impacts on the environment from the disposal of radioactive, hazardous, and mixed wastes.

Stabilization refers to techniques that chemically reduce the hazard potential of a waste by converting the contaminants into less soluble, mobile, or toxic forms. The physical nature and handling characteristics of the waste are not necessarily changed by stabilization.

Solidification refers to techniques that encapsulate the waste, forming a solid material, and does not necessarily involve a chemical interaction between the contaminants and the solidifying additives. The product of solidification, often known as the waste form, may be a monolithic block, a clay-like material, a granular particulate, or some other physical form commonly considered “solid.”

Solidification as applied to fine waste particles, typically 2 mm or less, is termed ***microencapsulation*** and that which applies to a large block or container of wastes is termed ***macroencapsulation***.

Solidification can be accomplished by a chemical reaction between the waste and solidifying reagents or by mechanical processes. Contaminant migration is often restricted by decreasing the surface area exposed to leaching and/or by coating the wastes with low-permeability materials. The combined process of solidification/stabilization mixes wastes, soils, and sludges with treatment agents to immobilize, both physically and chemically, the hazardous constituents in those substances. The technologies are not regarded as destructive techniques; rather, they eliminate or impede the mobility of contaminants.

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SOLIDIFICATION/STABILIZATION TECHNOLOGY RESOURCE MATRIX

Abstract Number	Document Title Document Ordering No.	Topics Addressed*	TECHNOLOGY TYPE				MEDIA			CONTAMINANTS							Source/Originating Office/Author
					Additives and Binder Reagents					Inorganic			Organic				
			Ex Situ	In Situ	Inorganic	Organic	Soil	Sludges	Industrial Wastes	Metals	Cyanides or Asbestos	Radioactive wastes	SVOCs	VOCs	Low level PCBs	TPH	
GUIDANCE AND POLICY DOCUMENTS																	
1	**Guide Specification for Construction, Solidification/Stabilization (S/S) of Contaminated Material.** USACE Document No. CEGS-02160	**[1]** **[2]**	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	Department of the Army, USACE (1998).
2	**Handbook for Stabilization/ Solidification of Hazardous Wastes.** EPA Document No. EPA/540/2-86/001	**[1]** **[2]**	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓		✓	EPA-HWERL, ORD (1986).
3	**Innovative Site Remediation Technology: Design and Application, Volume 4, Stabilization/Solidification.** EPA Document No. EPA 542-B-97-007	**[1]** **[2]**	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	EPA-OSWER/AAEE (1997).
4	**Innovative Site Remediation Technology: Volume 4, Solidification/Stabilization.** EPA Document No. EPA 542-B-94-001	**[1]** **[2]**	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	EPA-OSWER/AAEE (1994).
5	**Stabilization and Solidification of Hazardous Wastes.**	**[1]** **[2]**	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓			Barth, E. and others. (1990). *Pollution Technology Review* No. 186.
6	**Stabilization/Solidification of CERCLA and RCRA Wastes: Physical Tests, Chemical Testing Procedures, Technology Screening, and Field Activities.** EPA Document No. EPA/625/6-89/022	**[1]**	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	EPA-CERI, RREL (1989).

***Topics Addressed:**

[1] Performance Evaluation or Testing Protocols	[3] Durability and Degradation
[2] Contaminant- or Waste-Specific Procedures	[4] Long-term Effectiveness

SOLIDIFICATION/STABILIZATION TECHNOLOGY RESOURCE MATRIX

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GUIDANCE AND POLICY DOCUMENTS (continued)																	
7	**Statutory Interpretive Guidance on the Placement of Bulk Liquid Hazardous Waste in Landfills.** OSWER Policy Directive No. 9487.00-2A	[1] [2]		☐					☐	☐	☐		☐	☐	☐	☐	EPA-OSWER/OSW (1986).
8	**Technical Resource Document: Solidification/Stabilization and Its Application to Waste Materials.** EPA Document No. EPA/530/R-93/012 NTIS Document No: PB93-237535	[1] [2]	☐	☐	☐	☐	☐	☐	☐	☐	☐		☐	☐	☐	☐	EPA-RREL, ORD (1993).
9	**Treatability Studies for Solidification/Stabilization of Contaminated Material.** USACE Technical Letter No. 1110-1-158	[1] [2]	☐	☐	☐	☐	☐	☐		☐	☐	☐	☐	☐	☐	☐	Department of the Army, USACE (1995).
OVERVIEW AND PROGRAM DOCUMENTS																	
10	**Engineering Bulletin: Solidification/ Stabilization of Organics and Inorganics.** EPA Document No. EPA/540/S-92/015	[1] [2]	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	EPA-OERR, ORD (1993).
11	**Guide to Improving the Effectiveness of Cement-Based Solidification/Stabilization.** PCA Publication No. EB211	[2]	☐	☐	☐	☐	☐	☐	☐	☐	☐		☐	☐	☐	☐	Conner, J.R. Portland Cement Association. (1997).
12	**Innovative Treatment Technologies: Annual Status Report, 8th Edition.** EPA Document No. EPA-542-R-96-010	[2]	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	EPA-OSWER (1996).

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OVERVIEW AND PROGRAM DOCUMENTS (continued)																	
13	**Portland Cement: A Solidification Agent for Low-Level Radioactive Waste.** INEL Technical Bulletin No. EGG-LLW-8843	[2]	☐		☐	☐			☐			☐					DOE - INEL, EG&G Idaho, Inc. (1991).
14	**Potential Solidification/Stabilization Projects Under the Superfund Program.** PCA Publication No. IS500	[2]	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Wilk, C.M. Portland Cement Association. (1994).
15	**Potential Solidification/Stabilization Superfund Projects - 1995 Update.** PCA Publication No. IS501	[2]	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Wilk, C.M. Portland Cement Association. (1995).
16	**Solidification/Stabilization of Wastes Using Portland Cement.** PCA Publication No. EB071	[1] [2]	☐		☐		☐	☐	☐	☐			☐	☐		☐	Adaska, A., and others. Portland Cement Association. Second Edition. (1998).
17	**Superfund Innovative Technology Evaluation Program: Technology Profiles, 9th Edition.** EPA Document No. EPA/540/R-97/502	[1] [2]	☐	☐	☐		☐	☐	☐	☐	☐		☐		☐	☐	EPA-CERI (1996).

***Topics Addressed:**

[1] Performance Evaluation or Testing Protocols	[3] Durability and Degradation
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			Ex Situ	In Situ	Inorganic	Organic	Soil	Sludges	Industrial Wastes	Metals	Cyanides or Asbestos	Radioactive wastes	SVOCs	VOCs	Low level PCBs	TPH	
STUDIES AND DEMONSTRATIONS																	
18	**Chemfix Technologies, Inc. Solidification/Stabilization Process: Applications Analysis Report.** EPA Document No. EPA/540/A5-89/011 NTIS Document No. PB-91-187054	[1] [2]	□		□		□	□	□	□					□		EPA-RREL, ORD (1991).
19	**Evaluation of Solidification/ Stabilization for Treatment of a Petroleum Hydrocarbon-Contaminated Sludge from Fort Polk Army Installation, Louisiana.** NTIS Document No. ADA-320-253/8	[1] [2]	□		□			□		□						□	Channell, M.G. and K.T. Preston. U.S. ACE-WES (1996).
20	**Evaluation of Solidification/ Stabilization Treatment Processes for Municpal Waste Combustion Residues.** EPA Document No. EPA/600/R-93/167 NTIS Document No: PB-93-229870	[1] [2]	□		□				□	□							EPA- RREL, ORD (1993).
21	**HAZCON Solidification Process, Douglassville, PA: Applications Analysis Report.** EPA Document No. EPA/540/A5-89/001 NTIS Document No. PB-89-206031	[1] [2]	□		□		□			□			□	□	□	□	EPA-RREL, ORD (1989).
22	**International Waste Technologies/ Geo-Con In Situ Stabilization/ Solidification: Applications Analysis Report.** EPA Document No. EPA/540/A5-89/004 NTIS Document No. PB-90-269085	[1] [2]		□	□		□			□				□	□		EPA-RREL, ORD (1990).

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SOLIDIFICATION/STABILIZATION TECHNOLOGY RESOURCE MATRIX																	
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STUDIES AND DEMONSTRATIONS (continued)																	
23	**Investigation of Test Methods for Solidified Waste Evaluation - A Cooperative Program.** Report EPS 3/HA/8	[1] [2]	✓		✓		✓	✓	✓	✓	✓		✓	✓	✓	✓	Environment Canada/EPA/Alberta Environment (1991).
24	**Literature Review of Mixed Waste Components: Sensitivities and Effects Upon Solidification/Stabilization in Cement-Based Matrices.** NTIS Document No. ORNL/TN-12656	[2]	✓		✓		✓	✓	✓	✓		✓	✓	✓	✓	✓	Mattus, C.H. and T.M. Gilliam. DOE-ORNL (1994).
25	**Onsite Engineering Report for Solidification/Stabilization Treatment Testing of Contaminated Soils.** NTIS Document No. PB-93-166965/AS	[1] [2]	✓		✓		✓			✓							EPA-RREL, ORD (1993).
26	**Physical and Morphological Measures of Waste Solidification Effectiveness.** EPA Document No. EPA/600/D-91/164 NTIS Document No. PB91-226340/XAB	[1]	✓		✓		✓			✓			✓	✓	✓	✓	EPA-RREL, ORD/ AWMA (1991).
27	**Project Summary: Evaluation of Solidification/Stabilization as a Best Demonstrated Available Technology for Contaminated Soils.** EPA Document No. EPA/600/S2-89/013 NTIS Document No. PB89-169908	[1]	✓		✓		✓			✓			✓	✓	✓	✓	EPA-RREL, ORD (1990).
28	**Project Summary: Interference Mechanisms in Waste Stabilization/Solidification Process.** EPA Document No. EPA/600/S2-89/067	[1] [3] [4]	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	EPA-RREL, ORD (1990).

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STUDIES AND DEMONSTRATIONS (continued)																	
29	**Project Summary: Onsite Engineering Report for Solidification/Stabilization Treatment Testing of Contaminated Soils.** EPA Document No. EPA/600/SR-93/051	[1] [2]	✓		✓		✓			✓							EPA-RREL, ORD (1993).
30	**Silicate Technology Corporation's Solidification/Stabilization Technology for Organic and Inorganic Contaminants in Soils. Applications Analysis Report.** EPA Document No. EPA/540/AR-92/010 NTIS Document No. PB-93-172948	[1] [2]	✓		✓		✓			✓			✓	✓		✓	EPA-RREL, ORD (1992).
31	**Silicate Technology Corporation Solidification/Stabilization Technology SITE Demonstration at the SELMA Pressure Treating Site, Selma, CA. Technology Evaluation Report.** EPA Document No. EPA/540/R-95/010. NTIS Document No. PB-95-255709	[1] [2]	✓		✓		✓			✓			✓	✓		✓	EPA- RREL, ORD (1995).
32	**Soliditech, Inc. Solidification/ Stabilization Process, Applications Analysis Report.** EPA Document No. EPA/540/A5-89/005 NTIS Document No. PB-91-129817	[1] [2]	✓		✓		✓		✓	✓			✓	✓	✓	✓	EPA-RREL, ORD (1990).
33	**Stabilization of Heavy Metals with Portland Cement: Research Synopsis.** PCA Publication No. IS007	[1] [2]	✓	✓	✓		✓			✓							Wilk, C.M. Portland Cement Association. (1997).

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STUDIES AND DEMONSTRATIONS (continued)																	
34	**Technology Evaluation Report: Chemfix Technologies, Inc. Solidification/Stabilization Process, Clackamas, Oregon.** EPA Document No. EPA/540/5-89/011a NTIS Document No. PB-91-127696	[1] [2]	✓		✓		✓	✓	✓	✓							EPA-RREL, ORD (1990).
35	**Technology Evaluation Report: SITE Program Demonstration Test, HAZCON Solidification, Douglassville, Pennsylvania.** EPA Document No. EPA/540/5-89/001a NTIS Document No. PB-89-158810	[1] [2]	✓		✓		✓			✓			✓	✓	✓	✓	EPA-RREL, ORD (1989).
36	**Technology Evaluation Report: SITE Program Demonstration Test, International Waste Technologies In Situ Stabilization/Solidification, Hialeah, Florida** EPA Document No. EPA/540/5-89/004a NTIS Document No. PB-89-194161	[1] [2]		✓	✓		✓			✓				✓	✓		EPA-RREL, ORD (1990).
37	**Technology Evaluation Report: SITE Program Demonstration Test, Soliditech, Inc. Solidification/ Stabilization Process** EPA Document No. EPA/540/5-89/005a NTIS Document No. PB-91-129817	[1] [2]	✓		✓		✓		✓	✓			✓	✓	✓	✓	EPA-RREL, ORD (1990).

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[1] Performance Evaluation or Testing Protocols	[3] Durability and Degradation
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			TECHNOLOGY TYPE				MEDIA			CONTAMINANTS							
					Additives and Binder Reagents					Inorganic			Organic				
Abstract Number	Document Title Document Ordering No.	Topics Addressed*	Ex Situ	In Situ	Inorganic	Organic	Soil	Sludges	Industrial Wastes	Metals	Cyanides or Asbestos	Radioactive wastes	SVOCs	VOCs	Low level PCBs	TPH	Source/Originating Office/Author
WORKSHOPS AND CONFERENCE PROCEEDINGS																	
38	**Capability of Cementitious Materials in the Immobilization Process of Hazardous Waste Materials.**	[1] [2]	☐		☐		☐	☐	☐	☐							Poellmann, H. (1993). 15th International Conference on Cement Microscopy. p. 108-126.
39	**Cement-Based Solidification of Ferro-Alloy Flue Dusts.**	[1] [2]	☐		☐				☐	☐							Cohen, B., and J.G. Price. (1995). Canadian Institute of Mining, Metallurgy, and Petroleum. p. 297-308.
40	**Chemical Aspects of Incorporating Contaminated Soil Into Cold-Mix Asphalt.**	[1] [2]	☐			☐	☐			☐						☐	Testa, S.M. (1994). Superfund XV. p. 1439-1448.
41	**Chemical Stabilization of Contaminated Soils and Sludges Using Cement and Cement By-Products.**	[1] [2] [3] [4]	☐	☐	☐	☐	☐	☐		☐			☐	☐	☐	☐	Conner, J.R., Cotton, S. and Lear, P.R. (1992). First International Symposium on Cement Industry Solutions to Waste Management. p. 73-97.
42	**Chemistry and Microstructure of Solidified Waste Forms.**	[1] [2]	☐		☐		☐	☐	☐	☐							Spence, R.D. (Editor). (1993). Lewis Publishers.
43	**Designing a Better Matrix for Solidification/Stabilization of Hazardous Waste with the Aid of Bagasse (Lignin) as a Polymer Additive to Cement**	[2]	☐		☐	☐			☐	☐							Bourgeois, J.C and others. (1996). American Chemical Society. p. 416.
44	**Environmental Aspects of Stabilization and Solidification of Hazardous and Radioactive Wastes.** ASTM Publication No. 04-010330-56	[1] [2]	☐	☐	☐	☐	☐	☐	☐	☐		☐	☐	☐			Cote, P. and T.M.Gillian (Editors). (1989). ASTM STP-1033. Volume 1.
45	**Evaluation of Long-Term Effectiveness of Solidified and Stabilized Wastes.** Superfund XVI Proceedings	[1] [4]	☐		☐		☐			☐							Badamchian, B., and others. (1995). Superfund XVI. p. 599-608.

***Topics Addressed:**

[1] Performance Evaluation or Testing Protocols

[2] Contaminant- or Waste-Specific Procedures

[3] Durability and Degradation

[4] Long-term Effectiveness

SOLIDIFICATION/STABILIZATION TECHNOLOGY RESOURCE MATRIX

			TECHNOLOGY TYPE				MEDIA			CONTAMINANTS							
					Additives and Binder Reagents					Inorganic			Organic				
Abstract Number	**Document Title Document Ordering No.**	**Topics Addressed***	**Ex Situ**	**In Situ**	**Inorganic**	**Organic**	**Soil**	**Sludges**	**Industrial Wastes**	**Metals**	**Cyanides or Asbestos**	**Radioactive wastes**	**SVOCs**	**VOCs**	**Low level PCBs**	**TPH**	**Source/Originating Office/Author**
WORKSHOPS AND CONFERENCE PROCEEDINGS (continued)																	
46	**Immobilization Technology Seminar Speaker Slide Copies and Supporting Information.** EPA Document No. CERI-89-222	[1] [2] [3] [4]	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	EPA-RREL, ORD (1998).
47	**Laboratory and Field-Scale Test Methodology for Reliable Characterization of Solidified/ Stabilized Hazardous Wastes.**	[1]	✓		✓		✓	✓	✓	✓		✓					Gray, K.E., and others. (1995). Air & Waste Management Association International Symposium. p.575-582.
48	**Laboratory, Regulatory and Field Leaching of Solidified Waste.**	[1] [4]	✓		✓				✓	✓							Stegemann, J.A., Caldwell, R.J. and Shi, C. (1996). International Conference on Incineration and Thermal Treatment Technologies. p. 75-80.
49	**Material Handling Equipment for the Preparation of Wastes for Stabilization Treatment.** A&WMA Reprint No. 95-RP130.01	[1] [2]	✓				✓			✓							Lear, P.R., Schmitz, D.J. and Brickner, R.J. (1995). Air & Waste Management Association 88th Annual Meeting & Exhibition.
50	**Petrographic Techniques Applied to Cement Solidified Hazardous Wastes.**	[1] [3]	✓		✓		✓			✓					✓	✓	Wakeley, L.D., and others. (1992). 14th International Conference on Cement Microscopy. p. 274-289.
51	**Portland Cement-Based Solidification/Stabilization Treatment of Waste.**	[1] [2]	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	Wilk, C.M. (1998). Fourth International Symposium and Exhibition on Environmental Contamination in Central and Eastern Europe. To be available on CD-ROM or by contacting PCA.

***Topics Addressed:**

[1] Performance Evaluation or Testing Protocols	[3] Durability and Degradation
[2] Contaminant- or Waste-Specific Procedures	[4] Long-term Effectiveness

SOLIDIFICATION/STABILIZATION TECHNOLOGY RESOURCE MATRIX

Abstract Number	Document Title Document Ordering No.	Topics Addressed*	TECHNOLOGY TYPE				MEDIA			CONTAMINANTS							Source/Originating Office/Author
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			Ex Situ	In Situ	Inorganic	Organic	Soil	Sludges	Industrial Wastes	Metals	Cyanides or Asbestos	Radioactive wastes	SVOCs	VOCs	Low level PCBs	TPH	
WORKSHOPS AND CONFERENCE PROCEEDINGS (continued)																	
52	**Quality Analysis of Field Solidified Waste.**	[1]	☐		☐				☐	☐							Stegemann, J.A., and others. (1995). 5th Annual Symposium on Groundwater and Soil Remediation. p. 553-555.
53	**Recent Advances in Stabilization and Solidification.**	[1] [2] [4]	☐		☐		☐	☐	☐	☐							Cocke, D.L., and others. (1994). American Chemical Society. p. 537-541.
54	**Remediation of Oil Refinery Sludge Basin.**	[1] [2]		☐		☐	☐	☐		☐			☐	☐		☐	Adaska, W.S., Bruin, W.T. and Day, S.R. (1992). First International Symposium, Cement Industry Solutions to Waste Management. P. 119-134.
55	**Stabilization and Solidification of Hazardous, Radioactive, and Mixed Wastes.** ASTM Publication No. 04-011230-56	[1] [2] [4]	☐	☐	☐	☐	☐	☐	☐	☐		☐	☐	☐	☐		Gilliam T.M. and C.C.Wiles (Editors). (1992). ASTM STP-1123. Volume 2.
56	**Stabilization and Solidification of Hazardous, Radioactive, and Mixed Wastes.** ASTM Publication No. 04-012400-56	[1] [2] [3] [4]	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐		☐	Gilliam T.M. and C.C.Wiles (Editors). (1996). ASTM STP-1240. Volume 3.
57	**Synthesis, Crystal Chemistry and Stability of Ettringite, a Material With Potential Applications in Hazardous Waste Immobilization.**	[1] [2] [4]	☐		☐		☐	☐	☐	☐							McCarthy, G.J., and others. (1992). Materials Research Society Symposium.. p. 129-140.

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[1] Performance Evaluation or Testing Protocols	[3] Durability and Degradation
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SOLIDIFICATION/STABILIZATION TECHNOLOGY RESOURCE MATRIX																	
			TECHNOLOGY TYPE				MEDIA			CONTAMINANTS							
					Additives and Binder Reagents					Inorganic			Organic				
Abstract Number	Document Title Document Ordering No.	Topics Addressed*	Ex Situ	In Situ	Inorganic	Organic	Soil	Sludges	Industrial Wastes	Metals	Cyanides or Asbestos	Radioactive wastes	SVOCs	VOCs	Low level PCBs	TPH	Source/Originating Office/Author
WORKSHOPS AND CONFERENCE PROCEEDINGS (continued)																	
58	**The Present State-of-the-Art of Immobilization of Hazardous Heavy Metals in Cement-Based Materials.**	[3] [4]	✓		✓		✓	✓	✓	✓							Bonen, D. and S.L. Sarkar. (1994). Engineering Foundation Conference on Advances in Cement and Concrete. ASCE. p.481-498.
59	**Treatability Study of the Stabilization of Chromium-Contaminated Waste.**	[2]	✓		✓		✓	✓	✓	✓		✓					McGahan, J.F. and D. Martin. (1994). Proceedings of Waste Management '94. p. 1493-1497.
BOOKS																	
60	**A Surface Characterization of Priority Metal Pollutants in Portland Cement.**	[1] [2]	✓		✓				✓	✓							McWhinney, H.G. (1990). Doctoral Dissertation, Texas A&M University.
61	**Chemical Fixation and Solidification of Hazardous Wastes.**	[1] [2]	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	Conner, J.R. (1990). Van Nostrand Reinhold
62	**Effectiveness of Sulfur for Solidification/Stabilization of Metal Contaminated Wastes.**	[2]	✓		✓		✓			✓			✓	✓			Lin, S.L. (1995). Doctoral Dissertation, Georgia Institute of Technology.
63	**Permanence of Metals Containment in Solidified and Stabilized Wastes.**	[1] [3] [4]	✓		✓		✓		✓	✓							Klich, I. (1997). Doctoral Dissertation, Texas A&M University.
64	**Stabilization of Arsenic Wastes.** Report No. HWRIC RR-073	[2]	✓		✓	✓	✓	✓	✓	✓							Taylor, M. and R.W. Fuessle. (1994). Illinois DoE and Natural Resources and Hazardous Waste Research Information Center.

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Abstract Number	Document Title Document Ordering No.	Topics Addressed*	Ex Situ	In Situ	Inorganic	Organic	Soil	Sludges	Industrial Wastes	Metals	Cyanides or Asbestos	Radioactive wastes	SVOCs	VOCs	Low level PCBs	TPH	Source/Originating Office/Author
JOURNAL REFERENCES																	
65	**A Critical Review of Stabilization/Solidification Technology.**	[1] [2]	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Conner, J.R. and Hoeffner, S.L. (1998). *Critical Reviews in Environmental Science and Technology*. 28(4):397-462.
66	**A Long-Term Leachability Study of Solidified Wastes by the Multiple Toxicity Characteristic Leaching Procedure.**	[1] [4]	☐		☐				☐	☐							Lee, C.H., and others. (1994). *Journal of Hazardous Materials* 38:65-74.
67	**A Model to Predict the TCLP Leaching of Solidified Organic Wastes.**	[1]	☐		☐	☐	☐						☐	☐	☐	☐	Faschan, A., and others. (1996). *Hazardous Waste and Hazardous Materials* 13:333-350.
68	**A Proposed Protocol for Evaluation of Solidified Wastes.**	[1]	☐		☐	☐	☐	☐	☐	☐							Stegemann, J.A. and P.L. Cote. (1996). *Science of the Total Environment* 178:103-110.
69	**A Review of Solidification/Stabilization Interferences.**	[2]	☐		☐	☐	☐	☐	☐	☐		☐	☐	☐	☐	☐	Trussell, S. and R.D. Spence. (1994).*Waste Management* 14:507-519.
70	**Cement-Based Solidification/Stabilization of Lead-Contaminated Soil at a Utah Highway Construction Site.** PCA Publication No. RP332	[1] [2]	☐		☐		☐			☐							Wilk, C.M. and Arora, R. (1995). *Remediation, The Journal of Environmental Cleanup Costs, Technologies & Techniques*.
71	**Cement-Based Stabilization/ Solidification of Organic Contaminated Hazardous Wastes Using Na-Bentonite and Silica Fume.**	[2]	☐		☐				☐	☐			☐	☐			Shin, H.S. and K.S. Jun. (1995). *Journal of Environmental Science and Health* 30:651-668.
72	**Cement Binders for Organic Wastes.**	[2]	☐		☐		☐	☐	☐					☐			Owens, J. and S. Stewart. (1996). *Magazine of Concrete Research* 48:37-44.

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SOLIDIFICATION/STABILIZATION TECHNOLOGY RESOURCE MATRIX

Abstract Number	Document Title Document Ordering No.	Topics Addressed*	TECHNOLOGY TYPE				MEDIA			CONTAMINANTS							Source/Originating Office/Author
					Additives and Binder Reagents					Inorganic			Organic				
			Ex Situ	In Situ	Inorganic	Organic	Soil	Sludges	Industrial Wastes	Metals	Cyanides or Asbestos	Radioactive wastes	SVOCs	VOCs	Low level PCBs	TPH	
JOURNAL REFERENCES (continued)																	
73	**Durability Study of a Solidified Mercury-Containing Sludge.**	[1] [2] [3]	✓		✓			✓		✓							Yang, G. (1993). *Journal of Hazardous Materials* 34:217-223
74	**Effect of Adsorbents on the Leachability of Cement Bonded Electroplating Wastes.**	[1] [2]	✓		✓				✓	✓							Tamas, F.D., and others. (1992). *Cement and Concrete Research* 22:399-404.
75	**Effect of Carbonation on Microbial Corrosion of Concretes.**	[3]	✓		✓		✓	✓	✓								Ismail, N., and others. (1993). *Journal of Construction Management and Engineering* 20:133-138.
76	**Electron Microscopy of Heavy Metal Waste in Cement Matrices.**	[1] [2]	✓		✓		✓	✓	✓	✓							Ivey, D.G., and others. (1990). *Journal of Material Science* 25: 5055-5062.
77	**Evaluation of Solid Waste Stabilization Processes By Means of Leaching Tests.**	[1] [4]	✓		✓		✓			✓							Albino, V., and others. (1996). *Environmental Technology* 17:309-315.
78	**Evaluation of the Leaching Properties of Solidified Heavy Metal Wastes.**	[1] [2]	✓		✓			✓		✓							Herrera, E., and others. (1992). *Journal of Environmental Science and Health* A27:983-998.
79	**Factors For Selecting Appropriate Solidification/Stabilization Methods.**	[2]	✓		✓		✓	✓	✓	✓							Weitzman, L. (1990). *Journal of Hazardous Materials* 24:457-468.
80	**Feasilibilty of Using a Mixture of an Electroplating Sludge and a Calcium Carbonate Sludge as a Binder for Sludge Solidification.**	[1] [2]	✓		✓				✓	✓			✓				Yang, G. and K.L. Kao. (1994). *Journal of Hazardous Materials* 36:81-88.
81	**Fundamental Aspects of Cement Solidification and Stabilization.**	[1] [2] [4]	✓		✓		✓	✓	✓	✓		✓					Roy, A. and F.K. Cartledge. (Editors). (1997). *Journal of Hazardous Materials* 52:151-354.

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[1] Performance Evaluation or Testing Protocols	[3] Durability and Degradation
[2] Contaminant- or Waste-Specific Procedures	[4] Long-term Effectiveness

Abstract Number	Document Title Document Ordering No.	Topics Addressed*	TECHNOLOGY TYPE				MEDIA			CONTAMINANTS							Source/Originating Office/Author
					Additives and Binder Reagents					Inorganic			Organic				
			Ex Situ	In Situ	Inorganic	Organic	Soil	Sludges	Industrial Wastes	Metals	Cyanides or Asbestos	Radioactive wastes	SVOCs	VOCs	Low level PCBs	TPH	
JOURNAL REFERENCES (continued)																	
82	**Immobilization Mechanisms in Solidification/Stabilization of Cadmium and Lead Salts Using Portland Cement Fixing Agents.**	[1] [2]	☐		☐			☐		☐							Cartledge, F. and others. (1990). *Environmental Science and Technology* 24:867-873.
83	**Immobilization of Chromium in Cement Matrices.**	[1] [2]	☐		☐				☐	☐							Kindness, A., and others. (1994). *Waste Management* 14:3-11.
84	**Immobilization of Zinc and Lead From Wastes Using Simple and Fiber-Reinforced Lime Pozzolana Admixtures.**	[1] [2] [4]	☐		☐			☐	☐	☐							Debroy, M. and S.S. Dara. (1994). *Journal of Environmental Science and Health* A29:339-355.
85	**Immobilization Science of Cement Systems.**	[1] [2] [4]	☐		☐		☐	☐	☐	☐							Macphee, D.E. and F.P. Glasser. (1993). *MRS Bulletin* 3:66-71.
86	**Impact of Carbon Dioxide on the Immobilization Potential of Cemented Wastes: Chromium.**	[2] [3] [4]	☐		☐				☐	☐							Macias, A., and others. (1997). *Cement and Concrete Research* 27:215-225.
87	**Leachability of Lead From Solidified Cement-Fly Ash Binders.**	[1] [2]	☐		☐				☐	☐							Wang, S.Y. and C. Vipulanandan. (1996). *Cement and Concrete Research* 26:895-905.
88	**Long-Term Behaviour of Toxic Metals in Stabilized Steel Foundry Dusts.**	[1] [2] [4]	☐		☐				☐	☐							Andres, A., and others. (1995). *Journal of Hazardous Materials* 40:31-42.
89	**Long-Term Leaching of Metals From Concrete Products.**	[1] [2] [4]	☐		☐				☐	☐							Webster, M.T. and R.C. Loehr. (1996). *Journal of Environmental Engineering* 122:714-721.
90	**Long-Term Stability of Superplasticized Monoliths of a Solidified Electroplating Sludge.**	[1] [2]	☐		☐	☐		☐	☐	☐			☐	☐			Yang, G.C.C. and C.F. Chang. (1994). *Journal of Hazardous Materials* 37:277-283.

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SOLIDIFICATION/STABILIZATION TECHNOLOGY RESOURCE MATRIX

Abstract Number	Document Title Document Ordering No.	Topics Addressed*	TECHNOLOGY TYPE				MEDIA			CONTAMINANTS							Source/Originating Office/Author
					Additives and Binder Reagents					Inorganic			Organic				
			Ex Situ	In Situ	Inorganic	Organic	Soil	Sludges	Industrial Wastes	Metals	Cyanides or Asbestos	Radioactive wastes	SVOCs	VOCs	Low level PCBs	TPH	
JOURNAL REFERENCES (continued)																	
91	**Metals Distribution in Solidified/Stabilized Waste Forms After Leaching.**	**[1]**	✓		✓		✓	✓	✓	✓							Cheng, K. and P. Bishop. (1992). *Hazardous Waste and Hazardous Materials* 9:163-171.
92	**Ordinary Portland Cement Based Solidification of Toxic Wastes: The Role of OPC Reviewed.**	**[1]**	✓		✓			✓	✓	✓							Hills, C.D., and others. (1993). *Cement and Concrete Research* 23:196-212.
93	**Portland Cement Gives Concrete Support to Solidification/Stabilization.**	**[1]** **[2]**	✓		✓		✓	✓	✓	✓			✓	✓	✓	✓	Wilk, C.M. (1995). *Environmental Solutions May*.
94	**Potential Application of Ettringite Generating Systems for Hazardous Waste Stabilization.**	**[1]** **[2]**	✓		✓		✓	✓	✓	✓							Albino, V., and others. (1996). *Journal of Hazardous Materials* 51:241-252.
95	**Preliminary Investigation into the Effects of Carbonation on Cement-Solidified Hazardous Wastes.**	**[1]**	✓		✓				✓	✓							Lange, L.C., and others. (1996). *Environmental Science Technology* 30:25-30.
96	**Reaction of CO_2 With Alkaline Solid Wastes to Reduce Contaminant Mobility.**	**[1]** **[2]**	✓		✓				✓	✓							Reddy, K.J., and others. (1994). *Water Research* 28:1377-1382.
97	**Recent Findings on Immobilization of Organics as Measured by Total Constituent Analysis.**	**[1]** **[2]**	✓		✓	✓	✓					✓	✓	✓	✓	✓	Conner, J.R. (1995). *Waste Management* 15:359-470.
98	**Soil Stabilization Provides In-Situ Toxic Containment**	**[1]** **[2]**		✓	✓		✓			✓							Bornstein, R. and Wehr, F. (1991). *California Builder and Engineer*. CB&E: 35-36.
99	**Solidification/Stabilization of a Heavy Metal Sludge by a Portland Cement/Fly Ash Binding Mixture.**	**[1]** **[2]**	✓		✓			✓		✓							Roy, A., and others. (1991). *Hazardous Waste and Hazardous Materials* 8:33-41.

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[2] Contaminant- or Waste-Specific Procedures	[4] Long-term Effectiveness

SOLIDIFICATION/STABILIZATION TECHNOLOGY RESOURCE MATRIX

Abstract Number	Document Title Document Ordering No.	Topics Addressed*	TECHNOLOGY TYPE				MEDIA			CONTAMINANTS							Source/Originating Office/Author
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					Inorganic	Organic				Metals	Cyanides or Asbestos	Radioactive wastes	SVOCs	VOCs	Low level PCBs	TPH	
JOURNAL REFERENCES (continued)																	
100	**Solidification/Stabilization of Arsenic: Effects of Arsenic Speciation.**	[1] [2]	☐		☐		☐	☐	☐	☐							Buechler, P., and others. (1996). *Journal of Environmental Science and Health* A31:747-754.
101	**Solidification/Stabilization of Hazardous Waste: Evidence of Physical Encapsulation.**	[1] [2]	☐		☐				☐	☐							Roy, A., and others. (1992). *Environmental Science and Technology* 26:1349-1353.
102	**Solidification/Stabilization of Heavy Metals in Latex Modified Portland Cement Matrices.**	[1] [2] [3]	☐		☐	☐	☐	☐	☐	☐							Daniali, S. (1990). *Journal of Hazardous Materials* 24:225-230.
103	**Stabilization and Solidification of Lead in Contaminated Soils.**	[1] [2]	☐		☐		☐			☐							Lin. S.L., and others. (1996). *Journal of Hazardous Materials* 48:95-110.
104	**The Binding Chemistry and Leaching Mechanisms of Hazardous Substances in Cementious Solidification/ Stabilization Systems.**	[1] [2]	☐		☐		☐	☐	☐	☐							Cocke, D.L. (1990). *Journal of Hazardous Materials* 24:231-253.
105	**The Effects of Simulated Environmental Attack on Immobilization of Heavy Metals Doped in Cement-Based Materials.**	[1] [2] [3] [4]	☐		☐		☐	☐	☐	☐							Bonen, D. and S.L. Sarkar. (1995). *Journal of Hazardous Materials* 40:321-335.
106	**The History of Stabilization/Solidification Technology**	[1] [2]	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Conner, J.R. and Hoeffner, S.L. (1998). *Critical Reviews in Environmental Science and Technology*. 28(4): 325-396.
107	**The Interfacial Chemistry of Solidification/Stabilization of Metals.**	[1] [2]	☐		☐		☐	☐	☐	☐							Mollah, Y., and others. (1995). *Waste Management* 15:137-148.

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[2] Contaminant- or Waste-Specific Procedures	[4] Long-term Effectiveness

SOLIDIFICATION/STABILIZATION TECHNOLOGY RESOURCE MATRIX

Abstract Number	Document Title Document Ordering No.	Topics Addressed*	TECHNOLOGY TYPE: Ex Situ	TECHNOLOGY TYPE: In Situ	Additives and Binder Reagents: Inorganic	Additives and Binder Reagents: Organic	MEDIA: Soil	MEDIA: Sludges	MEDIA: Industrial Wastes	CONTAMINANTS: Inorganic: Metals	CONTAMINANTS: Inorganic: Cyanides or Asbestos	CONTAMINANTS: Inorganic: Radioactive wastes	CONTAMINANTS: Organic: SVOCs	CONTAMINANTS: Organic: VOCs	CONTAMINANTS: Organic: Low level PCBs	CONTAMINANTS: Organic: TPH	Source/Originating Office/Author
JOURNAL REFERENCES (continued)																	
108	**The Limitation of the Toxicity Characteristic Leaching Procedure for Evaluating Cement-Based Stabilized/ Solidified Waste Forms.**	[1]	☐		☐		☐	☐	☐	☐							Poon, C.S. and K.W. Lio. (1997). *Waste Management* 17:15-23.
109	**Time Effects of Three Contaminants on the Durability and Permeability of a Solidified Sand.**	[1] [3] [4]	☐		☐		☐			☐							Al'Tabbaa, A. and S. King. (1998). *Environmental Technology* 19:401-407.
110	**Treatment of Metal Industrial Wastewater by Flyash and Cement Fixation.**	[1] [2]	☐		☐				☐	☐							Weng, C.H. and C.P. Huang. (1994). *Journal of Environmental Engineering* 120:1470-1488.
111	**Variability of Field Solidified Waste**	[1] [2] [3] [4]	☐		☐				☐	☐							Stegemann, J.A., Caldwell, R.J. and Shi, C. (1997). *Journal of Hazardous Materials*. 52: 335-348.
BIBLIOGRAPHIES																	
112	**Hazardous Wastes - Fixation, Solidification, and Vitrification Excluding Radioactive Materials.** NTIS Document No. PB96-855945INI http://www.ntis.gov	[1] [2]	☐	☐	☐	☐	☐	☐	☐	☐	☐		☐	☐	☐	☐	DOE-Energy Science and Technology Database (1998).
113	**Radioactive Waste Processing - Fixation in Cements and Bitumens.** NTIS # PB96-855135INI http://www.ntis.gov	[1] [2]	☐	☐	☐	☐	☐	☐	☐	☐		☐					NTIS Bibliographic Database (1998).
IN SITU SOLIDIFICATION/STABILIZATION RESOURCES																	
114	**Engineering Issue: Considerations in Deciding to Treat Contaminated Soils In Situ.** EPA Document No. EPA/540/S-94/500 NTIS Document No. PB94-177771/XAB	[1] [2]		☐	☐	☐	☐	☐	☐	☐			☐	☐	☐	☐	EPA-OSWER (1993).

***Topics Addressed:**

[1] Performance Evaluation or Testing Protocols	[3] Durability and Degradation
[2] Contaminant- or Waste-Specific Procedures	[4] Long-term Effectiveness

SOLIDIFICATION/STABILIZATION TECHNOLOGY RESOURCE MATRIX

Abstract Number	Document Title Document Ordering No.	Topics Addressed*	TECHNOLOGY TYPE				MEDIA			CONTAMINANTS							Source/Originating Office/Author
					Additives and Binder Reagents					Inorganic			Organic				
			Ex Situ	In Situ	Inorganic	Organic	Soil	Sludges	Industrial Wastes	Metals	Cyanides or Asbestos	Radioactive wastes	SVOCs	VOCs	Low level PCBs	TPH	
IN SITU SOLIDIFICATION/STABILIZATION RESOURCES (continued)																	
115	**Handbook on In Situ Treatment of Hazardous Waste-Contaminated Soils.** EPA Document No. EPA/540/2-90/002 NTIS Document No. PB90-155607/XAB	[1] [2]		☐	☐	☐	☐	☐	☐	☐			☐	☐	☐	☐	EPA- RREL, ORD (1990).
116	**International Waste Technologies/ Geo-Con In Situ Stabilization/ Solidification: Applications Analysis Report** EPA Document No.EPA/540/A5-89/004 NTIS Document No. PB-90-269085	[1] [2]		☐	☐		☐			☐				☐	☐		EPA- RREL, ORD (1990).
117	**Overview of In Situ Waste Treatment Technologies.** NTIS Document No. DE92-018012/XAB	[2]		☐	☐	☐	☐	☐	☐	☐			☐	☐	☐	☐	Hyde, R.A., and others. (1992). EG&G Idaho, Inc.
118	**Pilot In Situ Auger Mixing Treatment of a Contaminated Site, Part I: Treatability Study.**	[1] [2]		☐	☐		☐			☐							Al'Tabbaa, A. and C. W. Evans. (1998). *Geotechnical Engineering* 131:52-59
119	**Recent Developments for In Situ Treatment of Metal-Contamianted Soils.** EPA Document No. EPA/542/R-97/004	[1] [2]		☐	☐		☐			☐							EPA-OSWER, TIO (1997).
120	**Technology Evaluation Report: SITE Program Demonstration Test, International Waste Technologies In Situ Stabilization/Solidification, Hialeah, Florida.** EPA Document No. EPA/540/5-89/004A NTIS Document No. PB-89-194161	[1] [2]		☐	☐		☐			☐				☐	☐		EPA-RREL, ORD (1989).

***Topics Addressed:**

[1] Performance Evaluation or Testing Protocols	[3] Durability and Degradation
[2] Contaminant- or Waste-Specific Procedures	[4] Long-term Effectiveness

<table>
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<tr><th>Inorganic</th><th>Organic</th><th>Metals</th><th>Cyanides or Asbestos</th><th>Radioactive wastes</th><th>SVOCs</th><th>VOCs</th><th>Low level PCBs</th><th>TPH</th></tr>
<tr><td colspan="2">OTHER RESOURCE GUIDES</td><td></td><td colspan="14">TECHNOLOGIES ADDRESSED</td><td></td></tr>
<tr><td>1</td><td>Bioremediation Resource Guide
EPA Document No. EPA/542-B-93/004
NTIS Document No. PB-94-112307</td><td>[1]
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[3]</td><td colspan="14">Bioremediation</td><td>EPA-OSWER, TIO (1993).</td></tr>
<tr><td>2</td><td>Ground Water Treatment Technology Resource Guide.
EPA Document No. EPA/542-B-94/009
NTIS Document No. PB-95-138657</td><td>[1]
[2]</td><td colspan="14">Vapor extraction, air stripping, and biological treatment</td><td>EPA-OSWER, TIO (1994).</td></tr>
<tr><td>3</td><td>Physical/Chemical Treatment Technology Resource Guide.
EPA Document No. EPA/542-B-94/008
NTIS Document No. PB-95-138665</td><td>[1]
[2]</td><td colspan="14">Soil washing/flushing, solvent extraction, thermal desorption, and chemical dehalogenation</td><td>EPA-OSWER, TIO (1994).</td></tr>
<tr><td>4</td><td>Soil Vapor Extraction (SVE) Enhancement Technology Resource Guide.
EPA Document No. EPA/542-B-95/003</td><td>[1]
[2]</td><td colspan="14">Air sparging, bioventing, hydraulic and pneumatic fracturing, and thermal enhancements</td><td>EPA-OSWER, TIO (1995).</td></tr>
<tr><td>5</td><td>Soil Vapor Extraction Treatment Technology Resource Guide.
EPA Document No. EPA/542-B-94/007
NTIS Document No. PB-95-138681</td><td>[1]
[2]</td><td colspan="14">Soil Vapor Extraction</td><td>EPA-OSWER, TIO (1994).</td></tr>
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***Topics Addressed:**

[1] Performance Evaluation or Testing Protocols	[3] Durability and Degradation
[2] Contaminant- or Waste-Specific Procedures	[4] Long-term Effectiveness

ABSTRACTS OF SOLIDIFICATION/STABILIZATION TECHNOLOGY RESOURCES

The abstracts below describe the contents of pertinent Solidification/Stabilization technology documents. The abstracts are organized alphabetically within each of the nine following document types:

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- Guidance and Policy Documents 31
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- Other Resource Guides 83

To quickly identify documents pertinent to your interest area, see the Solidification/Stabilization Technology Resource **Matrix** beginning on page 6 of this Guide. The documents in the matrix are organized alphabetically within the document types identified above. The document listings in the matrix can be cross-referenced with the abstracts using the code to the left of the document titles on the matrix. In an effort to limit the number of resources listed here, Records of Decision (RODs) and for most part, documents more than five years old are not included. Those seeking RODs may wish to contact the hotlines, dockets, or other sources.

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SOLIDIFICATION/STABILIZATION
RESOURCE GUIDE

GUIDANCE AND POLICY DOCUMENTS

1. Guide Specification for Construction, Solidification/Stabilization (S/S) of Contaminated Soil

Department of the Army. 1998. United States Army Corps of Engineers. Washington, D.C.

USACE Document No.: CEGS-02160

This guide specification covers the requirements for solidification/stabilization of materials contaminated with hazardous and toxic waste. The guide is a model specification for actual field work, and USACE and other project personnel can easily incorporate their site- and project-specific requirements electronically by downloading the document at USACE's TechInfo web site at <http://w2.hnd.usace.army.mil/techinfo/cegs/pdf/02160.pdf> **[1], [2]**.

2. Handbook for Stabilization/Solidification of Hazardous Wastes

U.S. Environmental Protection Agency. 1986. Hazardous Waste Engineering Research Laboratory. Office of Research and Development. Cincinnati, OH.

EPA Document No.: EPA/540/2-86/001

This handbook is intended for designers and reviewers of remedial action plans at hazardous waste disposal sites. The handbook provides information and guidance needed to judge the feasibility of stabilization/solidification technology in controlling contaminant migration from hazardous wastes disposed of on land. The document describes reagents and methodologies that have been useful in the stabilization/solidification of hazardous wastes; such information is useful to industrial and engineering firms that work with handling and disposal of hazardous waste, as well as regulatory agencies and environmental groups that need to assess the feasibility of technical solutions proposed at sites requiring remedial action **[1], [2]**.

3. Innovative Site Remediation Technology: Design and Application, Stabilization/Solidification, Volume 4.

U.S. Environmental Protection Agency. 1997. Office of Solid Waste and Emergency Response. Washington, DC.

EPA Document No.: EPA 542-B-97-007

The monograph covers the design, applications and implementation of stabilization/ solidification technologies and provides guidance on innovative processes considered ready for full-scale application. It is one of a series of monographs covering the description, evaluation, and limitations of the technology. This monograph's objective is to furnish guidance for experienced professionals with site remediation responsibility, and it is intended to aid in the implementation of stabilization and solidification technologies at specific sites **[1], [2]**.

4. Innovative Site Remediation Technology: Volume 4, Solidification/Stabilization

U.S. Environmental Protection Agency. 1994. Office of Solid Waste and Emergency Response. Washington, DC.

EPA Document No.: EPA 542-B-94-001

This monograph addresses innovative stabilization and solidification technologies that have been sufficiently developed for use in full-scale applications for site remediation and waste treatment. The purpose of the monograph is to further the use of innovative solidification and stabilization site remediation and waste-processing technologies, particularly where their use can provide better, more cost-effective performance than conventional methods. The monograph documents the current state of the technology for a number of innovative solidification and stabilization processes and considers all waste matrices to which solidification and stabilization can be reasonably applied, such as soils, liquids, and sludges **[1], [2]**.

5. Stabilization and Solidification of Hazardous Wastes

Barth E., and others. 1990. *Pollution Technology Review.* No. 186. Noyes Data Corporation. New York, NY.

This handbook provides a detailed overview of the state-of-the-art of solidification and stabilization of hazardous wastes through 1990 and includes inorganic and organic processes, as well as physical and chemical testing procedures used to evaluate solidification and stabilization technologies. Guidance is also provided on the selection and use of solidification and stabilization technologies through bench- and pilot-scale screening. Full-scale treatment operations are presented with numerous examples of ex situ and in situ technologies. In addition, quality control, safety, and environmental considerations for waste treatment, as well as equipment, costs, and regulatory requirements are discussed **[1], [2]**.

6. Stabilization/Solidification of CERCLA and RCRA Wastes: Physical Tests, Chemical Testing Procedures, Technology Screening, and Field Activities

U.S. Environmental Protection Agency. 1989. Center for Environmental Research Information. Risk Reduction Engineering Laboratory. Office of Research and Development. Cincinnati, OH.

EPA Document No.: EPA/625/6-89/022

A practical reference guide used for interpreting information on stabilization and solidification technologies including a comprehensive list of references through 1989. The document covers a wide range of applications useful for all technical and professional working in the stabilization/solidification field, including state and local environmental protection agencies, private industry, commercial treatment and disposal facilities, and environmental consultants, as well as EPA regional staff responsible for reviewing CERCLA remedial action plans and RCRA permit applications **[1]**.

7. Statutory Interpretive Guidance on the Placement of Bulk Liquid Hazardous Waste in Landfills

U.S. Environmental Protection Agency. 1986. Office of Solid Waste and Emergency Response. Washington, D.C.

OSWER Policy Directive No.: 9487.00-2A

Section 3004(c)(1) was added to the Resource Conservation and Recovery Act, as amended by the Hazardous and Solid Waste Amendments of 1984. This statutory interpretive guidance addresses the amendment's prohibition on the placement of bulk liquid hazardous wastes in landfills. The guidance discusses the legal requirements of the amendment and presents technical guidance to assist an owner or operator in complying with the amendment. The guidance recommends the use of an unconfined compressive strength test to determine that liquid wastes have been chemically stabilized or merely treated by the addition of a sorbant. The guidance recommends that unconfined compressive strength above 50 pounds per square inch be used to demonstrate that liquids in waste have been chemically stabilized **[1], [2]**.

8. Technical Resource Document: Solidification/Stabilization and Its Application to Waste Materials

U.S. Environmental Protection Agency. 1993. Risk Reduction Engineering Laboratory. Office of Research and Development, Washington, DC.

EPA Document No.: EPA/530/R-93/012
NTIS Document No.: PB93-237535

This technical resource document is intended for site managers considering solidification/stabilization as an option for treating hazardous wastes. It provides technology transfer to persons responsible for selection and design of solidification/stabilization treatment methods.

Information about solidification/stabilization is presented in detailed text descriptions supported by summary tables, checklists, and figures. The document gives the user a summary of solidification/stabilization technologies through 1993. The technology areas covered include binding agents and binding mechanisms, waste interferences with solidification/stabilization processes, solidification/stabilization treatment of organic contaminants, air emissions for solidification/stabilization processes, leaching mechanisms, long-term stability, reuse and disposal of solidification/stabilization treated waste, and economics. Information is also provided to clarify the limitations of solidification/stabilization technology and ongoing research to fulfill future development needs **[1], [2]**.

9. Treatability Studies for Solidification/Stabilization of Contaminated Material

Department of the Army. 1995. United States Army Corps of Engineers. Washington, D.C.

USACE Technical Letter No.: 1110-1-158

This technical letter provides information and guidance on scoping a treatability study for solidification/stabilization of contaminated material. The letter focuses on treatability studies for soils and sludges, and includes an outline of topics which should be considered for inclusion in a solidification/stabilization treatability scope of work **[1], [2]**.

OVERVIEW AND PROGRAM DOCUMENTS

10. Engineering Bulletin: Solidification/Stabilization of Organics and Inorganics.

U.S. Environmental Protection Agency. 1993. Office of Emergency and Remedial Response. Washington, DC. Office of Research and Development. Cincinnati, OH.

EPA Document No.: EPA/540/S-92/015

This bulletin provides general information on the applicability of solidification/stabilization technologies, limitations of solidification/stabilization, and a description of the solidification/stabilization treatment processes for organic and inorganic hazardous waste contaminants. The document summarizes factors that may interfere with the solidification/stabilization process and indicates the effectiveness of solidification/stabilization for general contaminant groups in soil and sludges. The report also identifies sites where full-scale solidification/stabilization has been implemented under CERCLA or RCRA **[1], [2]**.

11. Guide to Improving the Effectiveness of Cement-Based Solidification/Stabilization

Conner, J.R. 1997. Portland Cement Association. Skokie, IL.

PCA Publication No.: EB211

This guide discusses additives and techniques that can be applied to specific solidification problems such as development of set, compressive strength, and free liquids. The guide also provides lists and describes additives and techniques that can be applied to immobilization of specific hazardous constituents such as lead, cadmium, and chromium, as well as classes of constituents such as volatile organics, organo-metallics, and soluble salts. The guide includes a list of a variety of generic additives for specific desired stabilization/solidification effects, including those that can be used to control pH of wastes; to reduce, oxidize, and co-precipitate constituents; and to accelerate or retard set **[2]**.

12. Innovative Treatment Technologies: Annual Status Report, 8th Edition

U.S. Environmental Protection Agency. 1998. Office of Solid Waste and Emergency Response. Technology Innovation Office. Washington, DC.

EPA Document No.: EPA-542-R-96-010
http://clu-in.com

This yearly report and website database documents and analyzes the selection and use of innovative treatment technologies at Superfund sites and some non-Superfund sites under the jurisdiction of DoD and DOE. The information provides information for experienced technology users and those who are considering innovative technologies to clean up contaminated sites. In addition, the information will enable technology vendors to evaluate the market for innovative technologies in Superfund for the next several years. The database is used by the EPA Technology Innovation Office to track progress in the application of innovative treatment technologies. Alternative technologies are defined as alternatives to land disposal; innovative technologies include alternative technologies for which there is a lack of data on cost and performance. The ninth edition of the report and database (to be released in the Fall of 1998) also tracks the implementation and use of solidification/stabilization technologies. **[2]**.

13. Portland Cement: A Solidification Agent for Low-Level Radioactive Waste

U.S. Department of Energy. 1991. Idaho National Engineering Laboratory. EG&G Idaho, Inc.

INEL Technical Bulletin No.: EGG-LLW-8843

This technical bulletin provides an understanding of solidification of low-level radioactive waste to provide the structural stability required by 10 Code of Federal Regulations 61, Licensing Requirements for Land Disposal of Radioactive Waste. Topics addressed include regulatory requirements, current and past practices, packaging efficiencies, problem wastes, available solidification systems, and quality control **[2]**.

14. Potential Solidification/Stabilization Projects Under the Superfund Program

Wilk, C.M. 1994. Portland Cement Association. Skokie, IL.

PCA Publication No.: IS500

This publication contains a list of 166 existing and prospective Superfund projects involving the potential use of solidification/stabilization technology for waste remediation. The list is derived from a database developed and maintained by the Public Works Department of the Portland Cement Association. The document is designed to provide a quick reference for general information on each listed site, including location, industry type, contaminated media, contaminants, amount of contaminated media, project costs, record of decision (ROD) date, remediation program, EPA region number, and a site description. Following the listing is an index of sites grouped into industry types **[2]**.

15. Potential Solidification/Stabilization Superfund Projects - 1995 Update

Wilk, C.M. 1995. Portland Cement Association. Skokie, IL.
PCA Publication No.: IS501

This publication describes 42 Superfund cleanup projects involving the use of solidification/stabilization technology as part of the cleanup or site remedy. The list is mostly derived from EPA's Records of Decisions signed in Fiscal Year 1993 and 1994. The publication is an update to PCA's 1994 publication - Potential Solidification/Stabilization Projects Under the Superfund Program (IS500) **[2]**.

16. Solidification/Stabilization of Wastes Using Portland Cement

Adaska A., and others. Second Edition. 1998. Portland Cement Association. Skokie, IL.
PCA Publication No.: EB071

This engineering bulletin clarifies the role of Portland cement in the solidification/stabilization of hazardous wastes and is intended for consulting engineers, material suppliers, government officials, waste site owners, and the general public. The publication summarizes the chemistry of Portland cement and the cement hydration process as influenced by solidification/stabilization treatment additives, and organic and inorganic contaminants. In addition, the report discusses the regulatory basis for use of solidification/stabilization and outlines the various test methods for treatment characterization **[1], [2]**.

17. Superfund Innovative Technology Evaluation Program: Technology Profiles, 9th Edition

U.S. Environmental Protection Agency. 1996. National Risk Management and Research Laboratory. Office of Research and Development. Cincinnati, OH.

EPA Document No.: EPA/540/R-97/502

The Superfund Innovative Technology Evaluation (SITE) Program evaluates new and promising treatment, and monitoring, and measurement technologies for cleanup of hazardous waste sites. The program was created to encourage the development and routine use of innovative treatment technologies. As a result, the SITE Program provides environmental decision-makers with data on new, viable treatment technologies that may have performance or cost advantages compared to traditional treatment technologies. Each technology profile presented in the document contains the following: (1) a technology developer and process name; (2) a technology description, including a schematic diagram or photograph of the process; (3) a discussion of waste applicability; (4) a project status report; and 5) EPA project manager and technology developer contacts. The profiles also include summaries of demonstration results if available.

The technology description and waste applicability sections are written by the developer. EPA prepares the status and demonstration results sections **[2]**.

STUDIES AND DEMONSTRATIONS

18. Chemfix Technologies, Inc. Solidification/Stabilization Process: Applications Analysis Report

U.S. Environmental Protection Agency. 1991. Risk Reduction Engineering Laboratory. Office of Research and Development. Cincinnati, OH.

EPA Document No.: EPA/540/A5-89/011
NTIS Document No.: PB-91-187054

This Applications Analysis Report evaluates the treatment efficiency of the Chemfix Technologies, Inc. (Chemfix), solidification/stabilization technology for on-site treatment of soils contaminated with polychlorinated biphenyls, lead, copper, and other metals. The Chemfix demonstration was conducted under EPA's Superfund Innovative Technology Evaluation Program in March 1989, at the Portable Equipment Salvage Company site in Clackamas County, Oregon. The Chemfix treatment process was evaluated based on contaminant mobility, measured by numerous leaching tests; structural integrity of the solidified material, measured by physical and engineering tests and morphological examinations; and an economic analysis, using cost information supplied by Chemfix and supplemented by information generated during the demonstration. This report summarizes the results of the Chemfix demonstration, the vendor's design and test data, and other laboratory and field applications of the technology. It discusses the advantages, disadvantages, and limitations as well as estimated costs of the technology **[1], [2]**.

19. Evaluation of Solidification/Stabilization for Treatment of a Petroleum Hydrocarbon Contaminated Sludge from Fort Polk Army Installation, Louisiana

Channell, M.G., and K.T. 1996. Preston. Army Corps of Engineers - Waterways Experiment Station, Vicksburg, MS.

NTIS Document No.: ADA-320-253/8

This study used solidification/stabilization to treat the oily sludge found in the vehicle washrack oil-water separators. Solidification/stabilization is usually used to treat soils and sludges that contain heavy metals. Organic compounds, such as petroleum hydrocarbons found in the sludge, interfere with the setting of the solidification binding materials and thus are typically not treated using solidification/stabilization. This study incorporates the use of dicalcium silicate as an additive to the solidification process to increase the strength and reduce the leachability of the petroleum hydrocarbons found in the sludge. This study shows that dicalcium silicate improves the handling characteristics of the sludge and reduces contaminant leachability from the washrack sludge **[1], [2]**.

20. Evaluation of Solidification/Stabilization Treatment Processes for Municipal Waste Combustion Residues

U.S. Environmental Protection Agency. 1993. Risk Reduction Engineering Laboratory. Office of Research and Development. Cincinnati, OH.

EPA Document No.: EPA/600/R-93/167
NTIS Document No.: PB-93-229870

This report provides results of evaluations conducted to determine the effectiveness of solidification/stabilization processes, as well as information useful in designing and evaluating solidification/stabilization processes for treating municipal waste combustion residue. A full factorial experimental design was used to evaluate five solidification/stabilization processes to treat bottom ash, air pollution, control residue, and combined ash. The solidification/ stabilization processes included a control using Portland cement only, as well as Portland cement with soluble silicates, dry carbonaceous material, and other proprietary additives; cement kiln dust and proprietary additives; and soluble phosphates. The evaluations included analysis of chemical composition, physical properties, durability, and leaching characteristics. Based on comparison of untreated and treated residues, the solidification/stabilization processes evaluated generally did not decrease the potential for the release of target contaminants, including metals, dioxins, and furans. However, a phosphate process did reduce the potential of lead to be released **[1], [2]**.

21. HAZCON Solidification Process, Douglassville, PA: Applications Analysis Report

U.S. Environmental Protection Agency. 1989. Risk Reduction Engineering Laboratory. Office of Research and Development. Cincinnati, OH.

EPA Document No.: EPA/540/A5-89/001
NTIS Document No.: PB-89-206031

This Applications Analysis Report evaluates the treatment efficiency of the HAZCON solidification/stabilization technology for on-site treatment of soils containing a wide range of organic and heavy metal contaminants. The HAZCON demonstration was conducted under EPA's Superfund Innovative Technology Evaluation Program in October 1987, at the Douglassville, Pennsylvania, Superfund site. The HAZCON treatment process was evaluated based on contaminant mobility, measured by numerous leaching tests; structural integrity of the solidified material, measured by physical and engineering tests and morphological examinations; and economic analysis, using cost information supplied by HAZCON and supplemented by information generated during the SITE demonstration. This report summarizes the results of the HAZCON SITE demonstration, the vendor's design and test data, and other laboratory and field applications of the technology. It discusses the advantages, disadvantages, and limitations as well as estimated costs of the technology **[1], [2]**.

22. International Waste Technologies/Geo-Con In Situ Stabilization/Solidification: Applications Analysis Report

U.S. Environmental Protection Agency. 1990. Risk Reduction Engineering Laboratory. Office of Research and Development. Cincinnati, OH.

EPA Document No.: EPA/540/A5-89/004
NTIS Document No.: PB-90-269085

This Application Analysis Report evaluates the International Waste Technologies HWT-20 additive and the Geo-Con, Inc., deep-soil-mixing equipment for an in situ stabilization/ solidification process and its applicability as an on-site treatment method for waste site cleanup. The in situ treatment technology demonstration was conducted under EPA's Superfund Innovative Technology Evaluation Program in April 1988, at the General Electric Company electric service shop in Hialeah, Florida. Soil at the site contained polychlorinated biphenyls and localized concentrations of volatile organics and heavy metal concentrations. This report discusses the in situ process based on test results of the demonstration, as well as other data provided by the technology developer and the general capabilities of cement-based systems. It also discusses the applicability of the technology to other sites **[1], [2]**.

23. Investigation of Test Methods for Solidified Waste Evaluation - A Cooperative Program

Stegemann, J. A., and P.L. Cote. 1991. Environment Canada, U.S. Environmental Protection Agency, and Alberta Environment.

Report EPS 3/HA/8

This study was initiated by Environment Canada, in conjunction with Alberta Environment, and 15 American, Canadian, and European industrial participants involved in developing or marketing solidification technology. The purpose of the study was to develop and evaluate 16 laboratory test methods for characterizing the physical and chemical properties of a variety of solidified wastes. The cooperative objectives included (1) developing a set of laboratory test methods for characterizing the physical and chemical properties of a wide variety of solidified wastes, (2) evaluating the set of test methods by using real wastes and actual commercial solidification processes and by generating information on the reproducibility of the test methods, (3) developing an international database of properties of solidified wastes achievable with present technology to assist regulatory agencies and the waste treatment industry in setting guidelines, (4) providing a basis for continued development of test methods and mathematical models, and (5) promoting international use of the test methods for uniform comparative evaluation of solidified wastes. To maximize universal applicability of the tests, no attempt was made to simulate specific disposal conditions; therefore, the properties measured relate to the waste form and are independent of the disposal scenario **[1], [2]**.

24. Literature Review of Mixed Waste Components: Sensitivities and Effects Upon Solidification/Stabilization in Cement-Based Matrices

Mattus, C.H., and T.M. Gilliam. 1994. Oak Ridge National Laboratory. U.S. Department of Energy.

NTIS Document No.: ORNL/TN-12656

The report discusses the hydration mechanisms of Portland cement, mechanisms of retardation and acceleration of cement set-factors affecting the durability of waste forms, and regulatory limits as they apply to mixed wastes. This report also reviews (1) inorganic compounds that interfere with the development of cement-based waste forms and (2) radioactive species that can be immobilized in cement-based waste forms. In addition, the report also reviews organic species that may interfere with various waste-form properties **[2]**.

25. Onsite Engineering Report for Solidification/Stabilization Treatment Testing of Contaminated Soils

U.S. Environmental Protection Agency. 1993. Risk Reduction Engineering Laboratory. Office of Research and Development. Cincinnati, OH.

NTIS Document No.: PB-93-166965/AS

This report provides the full documentation of the Project Summary: Onsite Engineering Report for Solidification/Stabilization Treatment Testing of Contaminated Soils (see abstract number 29) **[1], [2]**.

26. Physical and Morphological Measures of Waste Solidification Effectiveness

Grube, W.E. 1991. U.S. Environmental Protection Agency. Risk Reduction Engineering Laboratory. Office of Research and Development. Cincinnati, OH.

EPA Document No.: EPA/600/D-91/164
NTIS Document No.: PB91-226340/XAB

The paper describes and discusses physical testing to characterize wastes treated by the Soliditech cement solidification/stabilization process. Morphological measurements included documented observations and measurements of the structure and form of the treated materials. The paper provides data to relate easily measured physical and morphological properties with intensive chemical extraction and solute leachability information obtained from standardized tests **[1]**.

27. Project Summary: Evaluation of Solidification/Stabilization as a Best Demonstrated Available Technology for Contaminated Soils

U.S. Environmental Protection Agency. 1990. Risk Reduction Engineering Laboratory. Office of Research and Development. Cincinnati, OH.

EPA Document No.: EPA/600/S2-89/013

NTIS Document No.: PB89-169908

This project summary evaluates the performance of solidification/stabilization as a means of treating contaminated soils at Superfund sites. Tests were conducted on artificially contaminated soils thought to be representative of the types of contaminated soils found at Superfund sites. Soils were solidified and stabilized using Portland cement, lime kiln dust, and a mixture of lime and fly ash. Solidification/stabilization significantly reduced the amount of metal salt contaminants released, as measured by the EPA Toxicity Characteristic Leaching Procedure (TCLP). Because of large losses of organics during the mixing process, the effect of solidification/stabilization on the organic leachate could not be quantitatively determined. The volatile and semivolatile organic contaminants appeared to decrease as a result of the solidification/stabilization process; however, this decrease can be attributed to the compounds' release to air during processing and curing. No correlation was observed between unconfined compressive strength and the results of the leaching tests **[1]**.

28. Project Summary: Interference Mechanisms in Waste Stabilization/Solidification Process

U.S. Environmental Protection Agency. 1990. Risk Reduction Engineering Laboratory. Office of Research and Development. Cincinnati, OH.

EPA Document No.: EPA/600/S2-89/067

This project summary presents key findings from a literature search and review concerning portland cement and pozzolan chemistry, the effects of admixtures on concrete setting characteristics, and the effects of common organic waste components on the physical and containment properties of the final treated waste product. These topics are presented so that conclusions may be drawn as to possible types of interferences that may be encountered in typical waste binder systems. The summary concludes that further experimental work is needed to obtain physical and chemical data about cementitious and asphaltic treatment systems and that sufficient basic information should be developed so that waste/binder interactions can be modeled and testing of each specific waste/binder combination for possible interference can be overcome **[1], [3], [4]**.

29. Project Summary: Onsite Engineering Report for Solidification/Stabilization Treatment Testing of Contaminated Soils

U.S. Environmental Protection Agency. 1993. Risk Reduction Engineering Laboratory. Office of Research and Development. Cincinnati, OH.

EPA Document No.: EPA/600/SR-93/051

This project summary evaluates the mechanism of lead fixation by portland cement, quicklime/fly ash, and cement kiln dust/fly ash on contaminated soil from a Superfund site. The study was performed to supply information to the best demonstrated available technology (BDAT) data base for soil remediation, used to develop soil standards for Land Disposal Restrictions. Results from the study indicate that soil can be treated to reduce the amount of leachable lead below the regulatory limit of 5 mg/L with the use of certain binder mixtures. Portland cement mixtures appear to provide the best results for stabilizing lead in contaminated soil used in the tests. The results of the study also indicate the organic content of the soil may effect the ability of binders to stabilize lead in the soil. Full characterization of soil being treated should therefore be performed to determine characteristics that may inhibit stabilization and what pretreatment procedures should be performed to improve stabilization **[1], [2]**.

30. Silicate Technology Corporation's Solidification/Stabilization Technology for Organic and Inorganic Contaminants in Soils. Applications Analysis Report

U.S. Environmental Protection Agency. 1992. Risk Reduction Engineering Laboratory. Office of Research and Development. Cincinnati, OH.

EPA Document No.: EPA/540/AR-92/010
NTIS Document No.: PB-93-172948

This Applications Analysis Report evaluates the solidification/stabilization treatment process of Silicate Technology Corporation (STC) for the on-site treatment of hazardous waste. The STC treatment technology demonstration was conducted under EPA's Superfund Innovative Technology Evaluation Program in November 1990, at the Selma Pressure Treating wood preserving site in Selma, California. STC's contaminated soil treatment process was evaluated based on contaminant mobility, measured by numerous leaching tests; structural integrity of the solidified material, measured by physical and engineering tests and morphological examinations; and an economic analysis, using cost information supplied by STC and supplemented by information generated during the demonstration. This report summarizes the results of the STC demonstration, the vendor's design and test data, and other laboratory and field applications of the technology. It discusses the advantages, disadvantages, and limitations as well as estimated costs of the technology **[1], [2]**.

Topics Addressed:

[1]	Performance Evaluation or Testing Protocols
[2]	Contaminant- or Waste-Specific Procedures
[3]	Durability and Degradation
[4]	Long-term Effectiveness

31. Silicate Technology Corporation Solidification/Stabilization Technology SITE Demonstration at the SELMA Pressure Treating Site, Selma, CA. Technology Evaluation Report

U.S. Environmental Protection Agency. 1995. Risk Reduction Laboratory, Office of Research and Development. Cincinnati, OH.

EPA Document No.: EPA/540/R-95/010.
NTIS Document No.: PB-95-255709

This Technology Evaluation Report evaluates the solidification/stabilization process of Silicate Technology Corporation (STC) for the on-site treatment of soils contaminated with organics, predominantly pentachlorophenol (PCP), and inorganics, mainly arsenic, chromium, and copper. The STC immobilization technology uses a proprietary product (FMS Silicate) to (1) chemically stabilize and microencapsulate organic and inorganic wastes and (2) physically solidify the contaminated soils. The STC demonstration was conducted under EPA's Superfund Innovative Technology Evaluation Program in November 1990, at the Selma Pressure Treating wood preserving site in Selma, CA. STC's contaminated soil treatment process was evaluated based on contaminant mobility, measured by numerous leaching tests, and structural integrity of the solidified material, measured by physical, engineering, and morphological examinations. This report provides a comprehensive description of the STC demonstration and its results, including a description of data collection activities, testing procedures, and quality assurance and quality control results **[1], [2]**.

32. Soliditech, Inc., Solidification/Stabilization Process, Applications Analysis Report

U.S. Environmental Protection Agency. 1990. Risk Reduction Engineering Laboratory. Office of Research and Development. Cincinnati, OH.

EPA Document No.: EPA/540/A5-89/005
NTIS Document No.: PB-91-129817

This Applications Analysis Report evaluates the treatment efficiency of the Soliditech, Inc. (Soliditech), solidification/stabilization technology for on-site treatment of soils contaminated with polychlorinated biphenyls, various metals, and petroleum hydrocarbons. The Soliditech demonstration was conducted under EPA's Superfund Innovative Technology Evaluation Program in December 1988, at the Imperial Oil Company/Champion Chemical Company Superfund site in Morganville, New Jersey. The Soliditech treatment process was evaluated based on contaminant mobility, measured by numerous leaching tests; structural integrity of the solidified material, measured by physical and engineering tests and morphological examinations; and an economic analysis, using cost information supplied by Soliditech and supplemented by information generated during the demonstration. This report summarizes the results of the Soliditech demonstration, the vendor's design and test data, and other laboratory and field applications of the technology. It discusses the advantages, disadvantages, and limitations as well as estimated costs of the technology **[1], [2]**.

33. Stabilization of Heavy Metals with Portland Cement: Research Synopsis

Wilk, C.M. 1997. Portland Cement Association. Skokie, IL.

PCA Publication No.: IS007

This publication summarizes research on establishing the mechanisms by which portland cement and portland cement-based reagents immobilize certain toxic heavy metals in inorganic form by solidification/stabilization treatment. The metals studied include lead, chromium, cadmium, arsenic, and mercury. This work confirms that cement-based stabilization involves far more than simple pH control, and suggests some possible mechanistic explanations for its effectiveness. The research also investigated certain additives designed to enhance stabilization mechanisms, and suggests modifications to further improve the immobility of metals **[1], [2]**.

34. Technology Evaluation Report: Chemfix Technologies, Inc. Solidification/ Stabilization Process, Clackamas, Oregon

U.S. Environmental Protection Agency. 1990. Risk Reduction Engineering Laboratory. Office of Research and Development. Cincinnati, OH.

EPA Document No.: EPA/540/5-89/011a
NTIS Document No.: PB-91-127696

This Technology Evaluation Report evaluates the treatment efficiency of the Chemfix Technologies, Inc. (Chemfix), solidification/stabilization technology for on-site treatment of soils contaminated with polychlorinated biphenyls, lead, copper, and other metals. The Chemfix demonstration was conducted under EPA's Superfund Innovative Technology Evaluation Program in March 1989, at the Portable Equipment Salvage Company site in Clackamas County, Oregon. The Chemfix treatment process was evaluated based on contaminant mobility, measured by numerous leaching tests; structural integrity of the solidified material, measured by physical and engineering tests and morphological examinations; and an economic analysis, using cost information supplied by Chemfix and supplemented by information generated during the demonstration. This report provides a comprehensive description of the Chemfix demonstration and its results, including a description of data collection activities, testing procedures, and quality assurance and quality control results **[1], [2]**.

35. Technology Evaluation Report: SITE Program Demonstration Test, HAZCON Solidification, Douglassville, Pennsylvania

U.S. Environmental Protection Agency. 1989. Risk Reduction Engineering Laboratory. Office of Research and Development. Cincinnati, OH.

EPA Document No.: EPA/540/5-89/001a
NTIS Document No.: PB-89-158810

This Technology Evaluation Report evaluates the treatment efficiency of the HAZCON solidification/stabilization technology for on-site treatment of soils containing a variety of organic and heavy metal contaminants. The HAZCON demonstration was conducted under EPA's Superfund Innovative Technology Evaluation Program in October 1987, at the Douglassville, Pennsylvania, Superfund site. The HAZCON treatment process was evaluated based on contaminant mobility, measured by numerous leaching tests; structural integrity of the solidified material, measured by physical and engineering tests and morphological examinations; and an economic analysis, using cost information supplied by HAZCON and supplemented by information generated during the demonstration. This report provides a comprehensive description of the HAZCON demonstration and its results, including a description of data collection activities, testing procedures, and quality assurance and quality control results **[1], [2]**.

36. Technology Evaluation Report: SITE Program Demonstration Test, International Waste Technologies In Situ Stabilization/Solidification, Hialeah, Florida

U.S. Environmental Protection Agency. 1989. Risk Reduction Engineering Laboratory. Office of Research and Development. Cincinnati, OH.

EPA Document No.: EPA/540/5-89/004a
NTIS Document No.: PB-89-194161

This Technology Evaluation Report evaluates the International Waste Technologies HWT-20 additive and the Geo-Con, Inc., deep-soil-mixing equipment for an in situ stabilization/solidification process and its applicability as an on-site treatment method for waste site cleanup. The in situ treatment technology demonstration was conducted under EPA's Superfund Innovative Technology Evaluation Program in April 1988, at the General Electric Company electric service shop in Hialeah, Florida. Soil at the site contained polychorinated biphenyls and localized concentrations of volatile organics and heavy metal concentrations. This report provides an interpretation of the available data and presents conclusions on the results of the demonstration, as well as the potential applicability of the technology at other sites **[1], [2]**.

Topics Addressed:

[1]	Performance Evaluation or Testing Protocols
[2]	Contaminant- or Waste-Specific Procedures
[3]	Durability and Degradation
[4]	Long-term Effectiveness

37. Technology Evaluation Report: SITE Program Demonstration Test, Soliditech, Inc. Solidification/Stabilization Process

U.S. Environmental Protection Agency. 1989. Risk Reduction Engineering Laboratory. Office of Research and Development. Cincinnati, OH.

EPA Document No.: EPA/540/5-89/005a
NTIS Document No.: PB-91-129817

This Technology Evaluation Report evaluates the treatment efficiency of the Soliditech, Inc. (Soliditech), solidification/stabilization technology for on-site treatment of soils contaminated with polychlorinated biphenyls, various metals, and petroleum hydrocarbons. The Soliditech demonstration was conducted under EPA's Superfund Innovative Technology Evaluation Program in December 1988, at the Imperial Oil Company/Champion Chemical Company Superfund site in Morganville, New Jersey. The Soliditech treatment process was evaluated based on contaminant mobility, measured by numerous leaching tests; structural integrity of the solidified material, measured by physical and engineering tests and morphological examinations; and an economic analysis, using cost information supplied by Soliditech and supplemented by information generated during the demonstration. This report provides a comprehensive description of the Soliditech demonstration and its results, including a description of data collection activities, testing procedures, and quality assurance and quality control results **[1], [2]**.

WORKSHOPS AND CONFERENCE PROCEEDINGS

38. Capability of Cementitious Materials in the Immobilization Process of Hazardous Waste Materials

Poellmann, H. 1993. In Proceedings of the 15th International Conference on Cement Microscopy. Dallas, TX. Pages 108-126.

This paper investigates and summarizes the capabilities of cementitious materials in immobilizing hazardous waste materials, including inorganic and organic contaminants. The fixation of chlorine, anions, heavy metals, and some organic compounds is discussed and strongly depends on the type of waste and cement used. Depending on the chemical and mineral compositions, various systems must be used, and detailed investigations are necessary for every waste material. In most cases, fixation in the crystal lattice plays an important role, and the formation of a microporous structure of the hydrated material intensifies the quality of the fixation and solidification process. The combination of different mineral reservoirs, for example anhydrous material and hydration products, can increase the immobilization process of hazardous materials. In the fixation process, incorporation of toxic substances in crystal lattices is necessary for the immobilization, but a dense microstructure can improve leaching tendencies **[1], [2]**.

39. Cement-Based Solidification of Ferro-Alloy Flue Dusts

Cohen, B., and J.G. Price. 1995. In Proceedings of the Canadian Institute of Mining, Metallurgy, and Petroleum on Waste Processing and Recycling in Mineral and Metallurgical Industries. Vancouver, Canada. Pages 297-308.

Flue dusts from ferro-alloy furnaces contain metal phases with a potential mobility that precludes them from being disposed of directly into landfills. This paper describes the use of cement-based solidification/stabilization in the treatment of such wastes. A review is given of the binding and retention mechanisms of metals within cement products. In this work, a model is presented for the containment of solid waste products where water is present only to promote cement hydration. The metals chromium and zinc are considered in detail due to their differing mechanisms of containment **[1], [2]**.

40. Chemical Aspects of Incorporating Contaminated Soil Into Cold-Mix Asphalt

Testa, S.M. 1994. In Proceedings Superfund XV: Environmental Conference and Exhibition for the Hazardous Materials/Hazardous Waste Management Industry. Washington, DC. Pages 1,439-48.

This paper presents the chemical aspects associated with the incorporation of petroleum hydrocarbons and metals-contaminated soil into an asphalt mix with an emphasis on pavement properties, leaching behavior, sensitivities to moisture damage, and functional group analysis. This study provides information that can be used to evaluate the stability of these constituents in soil after being incorporated as an ingredient in asphalt, and it indicates that cold-mix asphalt that incorporates contaminated soil will be highly stable and will perform adequately as an end product. Maximum chemical performance is achieved when the asphalt consists of high concentrations of pyridinic, phenolic, and ketone groups, which can be achieved by selectively choosing the source material. If the situation requires special stability or redundancy, small amounts of shale oil and lime can be used as additives. Situations and conditions that favor the presence of inorganic sulfur, monovalent salts, and high strength solutions in the asphalt should be avoided because these conditions decrease the chemical stability of the asphalt cement by (1) disruption the functional group aggregate bonds and (2) increasing the overall permeability **[1], [2]**.

41. Chemical Stabilization of Contaminated Soils and Sludges Using Cement and Cement By-Products

Conner, J.R., Cotton, S. and Lear, P.R. 1992. In Proceedings of the First International Symposium, Cement Industry Solution to Waste Management. Calgary, Alberta, Canada. Published by Canadian Portland Cement Association. Pages 73-97.

There are three basic elements in the chemistry of stabilized wastes: the waste, the stabilization reagents, and the environment in which the stabilized waste will exist. Proper formulation of the most cost-effective stabilization method that provides long-term stability requires a good understanding of the chemistry of the waste-reagent-disposal system. This paper describes the basics of this chemistry, relating them to a wide range of treatability study results and on-site project case histories. Stabilization data on both metals and low-level organics is presented **[1], [2], [3], [4]**.

42. Chemistry and Microstructure of Solidified Waste Forms

Spence, R.D. 1993. Editor. Lewis Publishers, Boca Raton, FL.

This book contains proceedings from the Chemistry and Microstructure of Solidified Waste Forms Symposium sponsored by the Environmental Division of the American Chemical Society at the National Meeting in New York City in 1991. These published proceedings contain written versions of most, but not all, of the papers presented orally. The symposium and its proceedings were limited to cementitious, or cement-based, solidified or stabilized waste forms. The book represents the level of knowledge of the chemistry, microstructure, and mechanisms of solidification/stabilization among prominent research centers in the United States and Europe. Authors were asked to summarize or review their organization's contribution over the years and to specifically introduce the reader to their organization's achievements and past publications. For example, information is presented on materials other than cement that are used to generate cementitious waste forms, including lime, fly ash, ground granulated blast furnace slag, and combinations. In addition, cementitious waste forms do not include waste encapsulated in polymers, such as bitumen, polyethylene, and vinyl ester styrene, or vitrified in glass waste forms. The book is intended to reflect the current state-of-the-art in the chemistry and microstructure of solidified waste forms. The book also informs professionals working the field about the experiences and accomplishments at other sites and provides a wealth of references **[1], [2]**.

43. Designing a Better Matrix for Solidification/Stabilization of Hazardous Waste With the Aid of Bagasse (Lignin) as a Polymer Additive to Cement

Bourgeois, J.C., and others. 1996. In Proceedings of the Spring National Meeting of the American Chemical Society. New Orleans, LA. Page 416.

The proceedings address the need for a better solidification/stabilization matrix to help solve the hazardous waste disposal problem. In this study, the waste-cement matrix is improved by incorporating a polymer additive into the matrix. The polymer enhances the encapsulation and penetration of the cement system into the interstitial spaces of the waste. To make the process more economically feasible, the source polymer was lignin obtained from the large excess of bagasse produced each year from sugar cane processors. The studies were conducted with lead as the initial heavy metal waste source **[2]**.

44. Environmental Aspects of Stabilization and Solidification of Hazardous and Radioactive Wastes, Volume 1, STP-1033

Cote, P., and T.M. Gilliam. 1989. Editors. American Society for Testing and Materials (ASTM). West Conshohocken, PA.

ASTM Publication Code No.: 04-010330-56

This Special Technical Publication contains 33 peer-reviewed papers of the 62 papers presented at the 4th International Hazardous Waste Symposium on Environmental Aspects of Stabilization/Solidification of Hazardous and Radioactive Wastes, held in Atlanta, Georgia, in 1987. Although the two scientific communities work with chemically hazardous or low-level radioactive waste and are faced with similar problems and technologies, the symposium represented the first forum for technology exchange between them. The symposium provided an occasion to understand the gap that separates the two groups, which use a shortly different vocabulary and are subject to markedly different regulations. The papers in this Special Technical Publication are grouped into four chapters: (1) processes, (2) regulatory aspects and testing methods, (3) laboratory evaluation, and (4) large-scale evaluation or demonstration **[1], [2]**.

45. Evaluation of Long-Term Effectiveness of Solidified and Stabilized Wastes

Badamchian, B., and others. 1995. In Proceedings Superfund XVI: Environmental Conference and Exhibition for the Hazardous Materials/Hazardous Waste Management Industry. Washington, DC. Pages 599-608.

This paper evaluates chemical, physical, and leaching data from field samples of solidified and stabilized wastes collected 6 years after the Soliditech, Inc., and Chemfix Technologies, Inc. Superfund Innovative Technology Evaluation demonstrations. The study is the first of a two-part study that evaluates the long-term effectiveness of the solidification/stabilization processes used to treat contaminated soils and hazardous wastes. Part II is a doctoral dissertation that evaluates the mineralogical alteration of the treated wastes over time and explores the fundamental mechanisms of degradation that affect the permanent containment of metals and the durability of solidified and stabilized wastes **[1], [4]**.

46. Immobilization Technology Seminar Speaker Slide Copies and Supporting Information

U.S. Environmental Protection Agency. 1989. Risk Reduction Engineering Laboratory. Office of Research and Development. Cincinnati, OH.

EPA Document No.: CERI-89-222

This document provides copies of speaker slides and supporting text regarding the use of solidification/stabilization and vitrification technologies to immobilize hazardous waste. The seminar material is comprised of eight sections: (1) immobilization processes overview; (2)

descriptions of solidification and stabilization technologies; (3) description of vitrification technology; (4) physical testing methods for determining effectiveness of solidification/stabilization processes; (5) chemical testing methods for determining effectiveness of solidification/stabilization processes; (6) technology screening procedures for determining if solidification/stabilization should be implemented; (7) field implementation procedures utilized for solidification/stabilization; and (8) quality assurance procedures for ensuring long-term performance **[1], [2], [3], [4]**.

47. Laboratory and Field-Scale Test Methodology for Reliable Characterization of Solidified/Stabilized Hazardous Wastes

Gray, K.E., and others. 1995. In Proceedings Air & Waste Management Association International Symposium on Field Screening Methods for Hazardous Wastes and Toxic Chemicals. Las Vegas, NV. Pages 575-82.

This paper presents a method for flow-through leach testing and discusses preliminary testing using strontium-doped, cement-based solidification/stabilization samples. The complementary and necessary characterization of the solidification/stabilization matrix, before and after testing, is discussed in relation to the total evaluation of the laboratory- and field-scale testing for predicting long-term performance of solidification/stabilization technology as well as its design and improvement. This report describes existing laboratory testing systems that are well suited for accelerated testing of solidification/stabilization waste forms. An overview of the available testing systems is given, and a prototype test, including preliminary test results, is discussed. The document also outlines complementary materials characterization methods currently being applied **[1]**.

48. Laboratory, Regulatory, and Field Leaching of Solidified Waste

Stegeman, J.A., Caldwell, R.J. and Shi, C. 1996. In Proceeding of the International Conference on Incineration and Thermal Treatment Technologies. Savannah, GA. Pages 75-80.

This paper presents the results of a field solidification study to validate a proposed laboratory evaluation protocol for solidified wastes. A project was initiated which involved placement of $63m^3$ of solidified electric arc furnace dust in a field test. Field leaching data were compared with the results from a low liquid-to-solid ratio distilled water batch extraction, a buffered extraction with a target pH of 5, and a regulatory leaching test based on 2 eq/kg acetic acid solution, for the contaminants boron, cadmium, lead, and mercury. Equilibrium modeling was performed to assist in interpretation of the laboratory and field data. The distilled water extraction test provided a good estimate of initial leachate concentrations in the field for boron, cadmium, chromium, and lead, but peak leachability of mercury was underestimated significantly. The pH 5 test was developed to estimate long-term availability of contaminants under severe environmental conditions. The pH regime created by the regulatory test is arbitrary and therefore less useful in predicting field leachability [1], [4].

49. Material Handling Equipment for the Preparation of Wastes for Stabilization Treatment

Lear, P.R., Schmitz, D.J. and Brickner, R.J. 1995. In Proceedings of the Air & Waste Management Association 88th Annual Meeting & Exhibition. San Antonio, TX.

A&WMA Paper Reprint No. 95-RP130.01

Stabilization treatment at hazardous waste sites contaminated with heavy metals can be complicated by the materials handling aspects of the waste material and associated debris. The proper materials handling equipment must be selected and assembled to efficiently handle, prepare, and/or separate the waste material and debris before the stabilization treatment process occurs. This paper discusses the types of materials handling equipment available, the efficacy of the equipment for dealing with waste material and debris, and the effect of the equipment on the stabilization treatment process based on full-scale experience **[1], [2]**.

50. Petrographic Techniques Applied to Cement Solidified Hazardous Wastes

Wakeley, L.D., and others. 1992. In Proceedings of the 14th International Conference on Cement Microscopy. Costa Mesa, CA. Pages 287-89.

The proceedings present data from petrographic and nondestructive analytical techniques applied to treated waste forms to show that such data is needed to determine if treated waste materials have stable phase composition and if their microstructures demonstrate uniform waste disposal. The cementitious solids of a solidified waste bind the waste physically and may bind it chemically, allowing it to pass performance tests required for its transportation and disposal. A largely separate family of standard test methods has evolved for solidified wastes because it represents an entirely separate use for cements. Some of these methods refer to or were based on standard methods from concrete technology. This paper reviews several of the concrete technology techniques to determine if they are appropriate for such waste forms and what unique and useful information they can provide for determining the likelihood of waste form durability **[1], [3]**.

51. Portland Cement-Based Solidification/Stabilization Treatment of Waste

Wilk, C.M. 1998. In Proceedings of the Fourth International Symposium and Exhibition on Environmental Contamination in Central and Eastern Europe.

This paper discusses the applicability of the portland cement-based solidification/stabilization technology to various wastes; basic cement chemistry relating to solidification/stabilization; tests used to design treatability studies and to verify treatment; basics on implementation of the technology in the field; and examples of actual projects **[1], [2]**.

52. Quality Analysis of Field Solidified Waste

Stegemann, J.A., and others. 1995. In Proceedings of the Fifth Annual Symposium on Groundwater and Soil Remediation. Toronto, Canada. Pages 553-55.

Factors responsible for variation in solidified products under field conditions, such as dosing and homogenization of binder and waste conditions, were reviewed to establish a method that could predict the magnitude of such variations and make solidification technology acceptable to regulators and waste generators. Random samples of solidified electric arc furnace dust were tested for bulk density, moisture content, specific gravity, contaminant concentrations, initial leachability, acid neutralization capacity, unconfined compressive strength, and freeze-thaw resistance. Variability in these properties were expressed in common statistical parameters and were compared with the design formulation prepared at laboratory scale. Within the field samples, chemical and leaching properties varied considerably. Despite the variations, the overall characteristics of the field samples met the performance criteria for physical encapsulation of contaminants recommended by Environment Canada's Wastewater Technology Center solidified waste evaluation protocols **[1]**.

53. Recent Advances in Stabilization and Solidification

Cocke, D.L., and others. 1994. In Proceedings Spring National Meeting of the American Chemical Society. San Diego, CA. Pages 537-41.

Recent advances in the use of cement, cementitious products, pozzolanic, and mixed environmental materials for stabilization and solidification of priority pollutants are discussed in the context of recently developed concepts and models. These advances in understanding are being achieved by using modern analytical techniques to examine the surface and bulk properties of solidification/stabilization systems. Substantial progress has been made in understanding the binding chemistry and leaching mechanisms of priority pollutants in cement-based systems; however, future challenges will require that waste management researchers extend such progress to more complex hazardous waste problems than those being attacked today. Commercial vendors will need to design more complex solidification/stabilization schemes to meet the growing use of this technology for hazardous waste management in complex waste systems containing both organics and inorganics. The recent findings are summarized and correlated with the design of improved solidification/stabilization systems by using effective models to aid in the long-term management of toxic wastes **[1], [2]**, **[4]**.

54. Remediation of Oil Refinery Sludge Basin

Adaska, W.S., Bruin, W.T. and Day, S.R. 1992. In Proceedings of the First International Symposium, Cement Industry Solutions to Waste Management. Calgary, Alberta, Canada. Published by Canadian Portland Cement Association. Pages 119-134.

This paper discusses the remediation of a 5.5 acre storm water sludge basin for an oil refinery company. The closure plan included a combination cement-bentonite slurry wall and jet grouting along the perimeter of the basin. The sludge and contaminated soil beneath the basin were solidified in place using a specifically developed soil mixing technique. The paper presents the site evaluation, closure plan, preconstruction testing programs, and field testing and construction that occurred and summarizes the results of the remediation **[1], [2]**.

55. Stabilization and Solidification of Hazardous, Radioactive, and Mixed Wastes, Volume 2, STP-1123

Gilliam, T.M., and C.C. Wiles. 1992. Editors. American Society for Testing and Materials (ASTM). West Conshohocken, PA.

ASTM Publication Code No.: 04-011230-56

This publication contains papers presented at the symposium on Stabilization and Solidification of Hazardous, Radioactive, and Mixed Wastes, held in Williamsburg, Virginia, in 1990. The symposium series provides a forum for technical exchange between researchers working with solidification/stabilization technologies for both low-level radioactive and chemically hazardous wastes. The papers presented in this publication are grouped into six sections: (1) regulatory and technical guidance; (2) speciality wastes: organics, ashes, and resins; (3) laboratory-scale leachability studies; (4) laboratory-scale process and development; (5) test method development; and (6) large-scale evaluation or demonstration **[1], [2], [4]**.

56. Stabilization and Solidification of Hazardous, Radioactive, and Mixed Wastes. Volume 3, STP-1240

Gilliam, T.M., and C.C. Wiles. 1996. Editors. American Society for Testing and Materials (ASTM). West Conshohocken, PA.

ASTM Publication Code No.: 04-012400-56

The conference proceedings present papers given at the symposium on Stabilization and Solidification of Hazardous, Radioactive, and Mixed Wastes, held in Williamsburg, Virginia, in 1993. The symposium series provides a forum for technical exchange between researchers working with solidification/stabilization technologies for both low-level radioactive and chemically hazardous waste. The scientific community has been focusing attention on understanding and predicting the long-term containment prospects of waste treated with this technology. Consequently, most papers presented in this publication address to some extent one or both of the two principal issues associated with long-term containment: leachability and durability. As defined in the overview of the proceedings, leachability refers to the release of contaminants from the waste upon exposure to an aqueous media, whereas durability refers to the ability of the waste to maintain its structural integrity upon exposure to expected environmental conditions **[1], [2], [3], [4]**.

57. Synthesis, Crystal Chemistry and Stability of Ettringite, a Material with Potential Applications in Hazardous Waste Immobilization

Mc Carthy, G.J., and others. 1992. In Proceedings of the Materials Research Society Symposium. Volume 245. Pages 129-140.

These proceedings present results of the synthesis, crystal chemistry, structure, and stability of ettringite with specific reference to the use of this mineral in hazardous waste immobilization. The potential connection between reductions in leachate hazardous element concentrations and ettringite formation led to the ongoing research program to investigate and then optimize the immobilization of hazardous elements in solid wastes and sludges particularly after solidification with ettringite-forming cementitious coal residuals or commercially-available cements. The long-term stability and hazardous element leachability of the ettringite-containing products is then evaluated. As research moves from the laboratory to the field, more attention to latent ettringite potential will be necessary. Future research should include a detailed evaluation of the stability of such composite waste forms under geochemically relevant conditions **[1], [2], [4]**.

58. The Present State-of-the-Art of Immobilization of Hazardous Heavy Metals in Cement-Based Materials

Bonen, D., and S.L. Sarkar. 1994. In Proceedings of an Engineering Foundation Conference on Advances in Cement and Concrete. American Society of Civil Engineers. Durham, NH. Pages 481-498.

This paper discusses the current state of knowledge involving solidification/stabilization of metals in cement-based materials. The common notion that no further reaction occurs between the waste and the binder after solidification/stabilization does not hold for Portland cement, because it overlooks possible long-term deterioration due to environmental corrosion. The report discusses the various types of chemical attack that Portland cement-based materials are prone to, including corrosion by soft water, ground water, and carbon dioxide-bearing water. This paper is aimed at stimulating awareness on the complexities involved in immobilizing waste in cementitious materials **[3], [4]**.

59. Treatability Study of the Stabilization of Chromium Contaminated Waste.

McGahan, J.F., and D. Martin. 1994. In Proceedings of Waste Management '94: Working Towards a Cleaner Environment, Technology and Programs for Radioactive Waste Management and Environmental Restoration. Tucson, AZ. Pages 1493-1497.

This paper presents a process developed to immobilize chromium in calcined uranyl nitrate mixed waste, resulting in a waste form that can be disposed of as radioactive, nonhazardous waste. A treatability test program was initiated to define the optimum conditions for the chemical reduction pretreatment step needed to stabilize the contaminated waste. Sodium dithionite was determined to be the reducing agent of choice. A dithionite demand experiment was run to determine the optimum dithionite dose. This dose, plus 67 percent excess, was added to each sample. Four stabilization systems at three dosage levels were investigated. The best performing reagent system was chosen for scale-up and more stringent performance testing. In one of the tested reagent systems involving Portland cement sodium silicate and dithionite, all of the samples exhibited TCLP extract concentrations for chromium well below the regulatory limit. One sample of Portland cement and blast furnace slag blend passed, and none of the samples of cement-fly ash and cement alone passed for leachable chromium. The scaled-up samples passed the performance criteria, and the process has successfully converted mixed waste into radioactive waste for disposal **[2]**.

BOOKS AND DISSERTATIONS

60. A Surface Characterization of Priority Metal Pollutants in Portland Cement

McWhinney, H.G. 1990. Doctoral Dissertation, Texas A&M University.

This dissertation characterizes the binding mechanisms of selected metal pollutants in Portland cement used in solidification/stabilization technologies. Surface analytical techniques were used to evaluate the relationship of lead, chromium, zinc, cadmium, mercury, and barium to the hydrated cementitious material. The location of metal ions with respect to the bulk and surface of the cement matrix was evaluated as a function of the interfacial phenomena of the alkaline medium in the synthetic wastes. Chromium tended to concentrate in the bulk, while lead concentrations were high on the surface. Zinc, cadmium, and mercury exhibited similar chemistries in the highly buffered alkaline medium, but their distribution in the final solidification product differed. Mercury, as mercuric oxide, occurred in isolated deposits within the cement matrix. Barium-doped cement contained large areas rich in calcium. There is also evidence that barium sulfate and carbonate will form. All cation-doped cement showed increases in surface carbonate content **[1], [2]**.

61. Chemical Fixation and Solidification of Hazardous Wastes

Conner, J.R. 1990. Van Nostrand Reinhold. New York, NY.

This reference book discusses in detail the principles of chemical fixation (stabilization) and solidification of hazardous wastes. Information is provided for using various inorganic binder materials, including Portland cement, soluble silicates, lime, fly ash, kiln dust, and other lime-based products. Organic binders also are described in the text. Hazardous wastes and waste sources, as well as in situ and ex situ treatment processes are discussed. The text also includes descriptions of commonly used test methods, including the EPA Extraction Procedure Toxicity Test, Multiple Extraction Procedure, Oily Wastes Extraction Procedure, and Toxicity Characteristic Leaching Procedure, as well as California's Waste Extraction Test (WET) and the American Nuclear Society ANS 16.1 Test Procedure. Information sources, computer applications, and research developments also are included **[1], [2]**.

62. Effectiveness of Sulfur for Solidification/Stabilization of Metal Contaminated Wastes

Lin, S.L. 1995. Doctoral Dissertation. Georgia Institute of Technology.

This research evaluates the use of over-supplied materials recovered from waste streams (such as sulfur) to stabilize lead-contaminated soils; such soils can then be used as construction materials, such as roadway fill. Sulfur polymer cement (SPC) was considered a possible binder or stabilizing agent for the solidification and stabilization of hazardous, low-level radioactive, and mixed wastes. Elemental sulfur recovered from industrial waste streams was also used to supplement asphalt cement by blending it with the asphalt to form sulfur-extended asphalt. The sulfur-extended asphalt is used for pavement and construction and has excellent performance characteristics. The research found that the use of sulfur alone (or SPC) could not stabilize lead compounds satisfactorily. However, more promising results were obtained with the use of sulfur modified by sodium sulfide or sodium sulfite. The sodium-sulfur compounds chemically react with the heavy metals and physicochemically bind them to form stable compounds, significantly reducing the leachability of the metals. Metal levels in sulfur-treated wastes may be reduced to the point that the wastes can be used in some forms of construction materials **[2]**.

63. Permanence of Metals Containment in Solidified and Stabilized Wastes

Klich, I. 1997. Doctoral Dissertation. Texas A&M University.

This dissertation reviews the current literature available on containing metals in solidified and stabilized wastes treated with inorganic binders, such as Portland cement, fly ash, and other soluble silicates. The research examines the mineralogic alterations of seven metal-bearing solidified and stabilized wastes that were landfilled or stored aboveground for up to 6 years. The extent of degradation after the 6 years was found to be slight to moderate; however, pervasive cracking was observed at the macro-, micro-, and submicroscopic scales. In addition, chemical weathering features were documented. The research verified that wastes treated with cement, like hardened concrete, are metastable both physically and chemically under ambient conditions.

Over time, treated wastes will attempt to reach equilibrium with the surrounding environment. Therefore, the same environmental concerns that affect the durability of concrete must be considered when evaluating the durability and permanence of cement-stabilized and solidified wastes. Burial of cement-based solidified and stabilized wastes in deleterious environmental zones, such as acid or saline soils, as well as fluctuating ground water systems, are not recommended **[1], [3], [4]**.

64. Stabilization of Arsenic Wastes

Taylor, M., and R.W. Fuessle. 1994. Illinois Department of Energy and Natural Resources and Hazardous Waste Research Information Center. Champaign, IL. Report No. HWRIC RR-073.

The focus of this research is the development and understanding of a treatment technology for arsenic wastes that are not wastewaters. The document addresses a research need by developing a greater microchemical and microstructural understanding of why stabilization works in some cases and not in others and by comparing methods of pretreatment to eliminate or minimize interferences and to predict whether the treatment will last or not. These guidelines aid in deciding which arsenic wastes are amenable to stabilization. The recommendations include pretreatment dosages and mix design parameters. These guidelines are intended to improve the design and operation of commercial arsenic stabilization processes **[2]**.

JOURNAL REFERENCES

65. A Critical Review of Stabilization/Solidification Technology

Conner, J.R. and Hoeffner. S.L. 1998. *Critical Reviews in Environmental Science and Technology*. 28(4): 397-462.

This article reviews the methods of solidification/stabilization critically in light of the current regulatory atmosphere that controls and often mandates their use. The processes and techniques of solidification/stabilization have matured into an accepted and important part of environmental technology. As a result, many methods have been promoted recently and offered for the treatment of hazardous and other wastes from industry, municipalities, and government sources. An overview of the technology is provided. The generic and proprietary solidification/stabilization processes (chemical, physical, and thermal) are described. Of those, six generic chemical processes that dominate the field and encompass nearly all the treatment work and proprietary products to date are discussed. Current and anticipated major waste streams using the technology today are summarized and the solidification/stabilization approach for each are reviewed **[1], [2]**.

66. A Long-Term Leachability Study of Solidified Wastes by the Multiple Toxicity Characteristic Leaching Procedure

Lee, C.H., and others. 1994. *Journal of Hazardous Materials*.

This paper discusses the use of the multiple toxicity characteristic leaching procedure (MTCLP) to evaluate the long-term leachability of solidified wastes. Two cement-based, solidified, mercury-containing wastes and one untreated waste were evaluated by the MTCLP to simulate

Topics Addressed:
[1] Performance Evaluation or Testing Protocols
[2] Contaminant- or Waste-Specific Procedures
[3] Durability and Degradation
[4] Long-term Effectiveness

the long-term leaching behavior of heavy metal contaminants in these wastes in an improperly designed sanitary landfill. The MTCLP combines multiple extraction procedure and the TCLP, which are being used by the EPA. The study presents the experimental procedures of the MTCLP as well as the results of the chemical analysis of leachates obtained from the MTCLP of the mercury-bearing wastes **[1], [4]**.

67. A Model to Predict the TCLP Leaching of Solidified Organic Wastes

Faschan, A., and others. 1996. *Hazardous Waste and Hazardous Materials*. 13:333-350.

This study evaluates the effects of organoclay adsorption on the Toxicity Characteristic Leaching Procedure results for solidified organic wastes. Linear adsorption isotherms were developed for the adsorption of 1,2-dichlorobenzene (DCB) and nitrobenzene (NB) by five organoclays on simulated wastes solidified with various combinations of Type I Portland cement. A model was developed to predict the leachability of organic wastes solidified using organoclays. The model is limited to predictions for nonionic organic compounds and predicts the slope of linear adsorption isotherms dependent on (1) the K_{ow} of the organic compound solidified and (2) the percent organic matter of the organoclay utilized. The predicted adsorption isotherm slope is then corrected using several factors developed in the study. One factor corrects for differences in actual leaching results compared to results predicted by the isotherm based on the encapsulation of the organic-organoclay mixture by cement. Another factor corrects for differences in actual and predicted leaching results due to different sample curing times **[1]**.

68. A Proposed Protocol for Evaluation of Solidified Wastes

Stegemann, J.A., and P.L. Cote. 1996. *Science of the Total Environment*. 178:103-110.

Solidification technologies are potentially useful for improving the chemical and physical properties of hazardous wastes to the extent that they are suitable for less expensive disposal or even utilization. Unfortunately, in most jurisdictions worldwide, there is no mechanism for reclassifying a treated, previously hazardous waste, as nonhazardous. In response to the need for such a mechanism, this study proposes a protocol of test methods for cement-based solidified wastes. The suggested test methods examine contaminant partitioning as a result of chemical specification, potential for slow release of contaminants, mobility of the contaminants in the solidified waste matrix, and the durability of the matrix. Most of the suggested tests are standards from the fields of hazardous and radioactive wastes, some of which have been evaluated in a cooperative study initiated by Environment Canada with vendors of solidification processes. Based on the performance of a solidified product in the tests, it is considered for four utilization and disposal scenarios, including unrestricted utilization, controlled utilization, segregated landfill, and sanitary landfill. The protocol represents a first attempt to develop a management tool for solidified waste that accounts for its physical and leaching characteristics in different disposal scenarios **[1]**.

69. A Review of Solidification/Stabilization Interferences

Trussell, S., and R.D. Spence. 1994. *Waste Management.* 14:507-519.

This paper reviews the literature on interferences between hazardous wastes and cement and the fundamental chemical mechanisms that inhibit the setting of cement. From this fundamental information, it is possible to reach some conclusions about the potential effects of most waste constituents even in the absence of particular studies on specific compounds. Decisions on the appropriate disposition of wastes containing both organic and inorganic compounds should first determine whether any waste constituents compromise the strength or stability of the waste form or are highly leachable. Often interferences can be mitigated decrease the leachability of the waste constituents. Organic and inorganic wastes, as well as low-level radioactive wastes are considered **[2]**.

70. Cement-Based Solidification/Stabilization of Lead-Contaminated Soil at a Utah Highway Construction Site

Wilk, C.M. and Arora, R. 1995. *Remediation, The Journal of Environmental Cleanup Costs, Technologies & Techniques*. Reprints available through PCA (PCA Publication No.: RP332).

This article describes portland cement-based solidification/stabilization treatment of heavy metal-contaminated soil. The soil was discovered during highway construction in West Jordan, Utah. The article includes a discussion of the excavation; size segregation; reduction of oversized particles; addition and mixture of portland cement and cement kiln dust; and beneficial use of the treated soil as a subbase for building a pavement for composting operations at a municipal landfill **[1], [2]**.

71. Cement-Based Stabilization/Solidification of Organic Contaminated Hazardous Wastes Using Na-Bentonite and Silica Fume

Shin, H.S., and K.S. Jun. 1995. *Journal of Environmental Science and Health.* 30:651-668.

This study investigates the use of (1) bentonite and briquette ash as adsorbents for organic components and heavy metals in industrial wastes and (2) silica fume as an admixture to improve the solidified wastes with cement. Chrome tanning wastes containing up to 1.5 percent organic carbon and 1.2 percent chromium were treated with sodium montmorillonite (bentonite) and briquette ash. The organic components and heavy metals of the waste were well adsorbed. Solidification of the waste, clay, and silica-fume mixtures produced a monolithic mass with high strength and very low leaching of the organic compounds and the metals. This study showed that bentonite and briquette ash could be successful adsorbents for the organic contaminant and heavy metals in industrial wastes, which enabled them to be treated by cement-based solidification. Also, the use of silica-fume was highly effective in achieving high compressive strength and low permeability. Cement-based solidification with the bentonite, briquette ash, and silica-fume gave solid products which set rapidly and were far stronger and more homogeneous than the sole cement-based solidification. The total organic carbon was reduced by 60 to 78 percent for the wastes tested compared with the conventional cement-based solidified waste, and the release of heavy metals was reduced by 52 to 70 percent **[2]**.

72. Cement Binders for Organic Wastes

Owens, J.W., and S. Stewart. 1996. *Magazine of Concrete Research*. 48:37-44.

Three cyclic hydrocarbons (benzene, toluene, and ortho-xylene), each a known volatile organic compound (VOC), is produced in large quantities by the synthetic chemical manufacturing industry. The hydrocarbons were loaded into Portland cement matrices and stored in a similar organic solvent, *o*-dichlorobenzene, for 2 months. The leaching characteristics of these three VOCs were measured using gas chromatography and a flame ionization detector. The objective of this study was to assess the comparative leaching characteristics of these organic contaminants in cement matrices stored in another organic solvent compared with storage in air. The leaching characteristics of benzene, toluene, and ortho-xylene from Portland cement stored in *o*-dichlorobenzene were compared with reported values for similar organic contaminants loaded into cement matrices stored in water. Results indicate that the leaching of benzene, toluene, and ortho-xylene from Portland cement is erroneously high when measured using a weight loss method **[2]**.

73. Durability Study of a Solidified Mercury-Containing Sludge

Yang, G.C.C. 1993. *Journal of Hazardous Materials.* 34:217-223.

This paper presents research findings on the durability of a solidified mercury-containing sludge. A sludge sample was obtained from a chloro-alkali plant and solidified using a commercially available sludge treatment agent (STA II). The solidified monoliths were subjected to physical and chemical durability tests. The physical durability tests (freezing/thawing and wetting/drying tests) were followed by measurements of unconfined compressive strength and mercury concentrations resulting from the Toxicity Characteristic Leaching Procedure (TCLP). The multiple TCLP was employed for the chemical durability test. The smaller the sludge-to-binder ratio was, the better the physical and chemical properties a solidified monolith would have. Test results showed that solidification using the binder STA II reduced the cumulative amount of mercury leached from 11 percent to less than 0.7 percent by weight **[1], [2], [3]**.

74. Effect of Adsorbents on the Leachability of Cement Bonded Electroplating Wastes

Tamas, F.D., and others. 1992. *Cement and Concrete Research.* 22:399-404.

Results from this study indicate that water-soluble cadmium and nickel salts are quantitatively transformed into insoluble hydroxides within Portland cement matrices; this suggests that other heavy metals capable of giving insoluble hydroxides in alkaline surroundings would behave similarly. Chromates and dichromates formed no insoluble hydroxides, but they were partly bound in the cement matrix. Adsorbents (silica fume, fly ash, and activated carbon), with the exception of fly ash, did not improve the bonding. The use of clinker instead of cement caused a more intensive bond. Chromium bonding appears to be affected by the presence of gypsum or its hydration products with clinker aluminates. However, further research is needed to determine if this sort of disposal is really risk-free, because carbonation may transform insoluble hydroxides to more soluble carbonates or even hydrocarbonates. In addition, research is necessary to determine the durability of the cemented products among extreme conditions, such as carbonation or other types of acid attack **[1], [2]**.

75. Effect of Carbonation on Microbial Corrosion of Concretes

Ismail, N., and others. 1993. *Journal of Construction Management and Engineering.* 20:133-138.

The objective of this study was to investigate the effect of carbonation on microbial corrosion of concretes. The carbonation process involves the reduction of surface pH of concrete and is the prerequisite for microbial corrosion to occur. Results showed that the carbonated surface layer of concrete accelerated the surface colonization of sulfur oxidizing bacteria (*Thiobacilli thioxidans*) and induced microbial corrosion. Corrosion rates corresponded well with the carbonation rates. The formation of gypsum and ettringite in cured products may further result in the complete decomposition of the hardened concrete **[3]**.

76. Electron Microscopy of Heavy Metal Waste in Cement Matrices

Ivey, D.G., and others. 1990. *Journal of Material Science.* 25:5055-5062.

In this study, cements were mixed with various amounts of chromium metal in the form of nitrates to simulate industrial waste. The mixtures were then investigated to better understand the distribution and stability of chromium contaminants within solidified and stabilized waste matrices. Chromium is known to accelerate the hydration reaction and strength development in cement, which may be of practical benefit. Electron microscopy techniques, including scanning electron and scanning transmission electron microscopy, were used to study the complex microstructures associated with the mechanisms of solidification/stabilization. Results showed that trivalent chromium is chemically contained within the cement structure, a feature that appears consistent with accelerating additives. Cement hydration retarders, such as divalent lead and zinc, tend not to be chemically contained, but rather may form insoluble salts and tend to precipitate as dense coatings on the hydrating phases. Accelerators, such as chromium, have soluble calcium salts and are thus more easily incorporated into the cement hydration products **[1], [2]**.

77. Evaluation of Solid Waste Stabilization Processes By Means of Leaching Tests

Albino, V., and others. 1996. *Environmental Technology.* 17:309-315.

The effectiveness of two novel stabilizing matrices were tested in systems where 5 or 10 percent of soluble nitrates of cadmium, chromium, copper, nickel, lead, and zinc were added. The matrices are based on blast furnace slag, fly ash, gypsum, hydrated lime, and Portland cement. They owe their effectiveness to the formation of calcium trisulphoaluminate and silicate hydrates. The study involved three leaching tests using deionized water, acetic acid/sodium acetate with a pH of 4.74 in a buffer solution, and controlled pH 4 nitric acid solution. In each test, metals were released to an extent that depends on the nature and initial metal concentration as well as on the matrix nature. The results of the leaching tests have shown that neither the prevailing entrapment mechanism can be understood, nor the long-term release behavior can be predicted from a single leaching test **[1], [4]**.

78 Evaluation of the Leaching Properties of Solidified Heavy Metal Wastes

Herrera, E., and others. 1992. *Journal of Environmental Science and Health.* A27:983-998.

The effects of three inorganic materials on the leaching properties of Type I Portland cement solidification matrix were studied. Cadmium nitrate and hydroxide sludges of cadmium and lead were used as the inorganic materials. Cure times of up to 28 days were studied. Leachability effects were determined by the Toxicity Characteristic Leaching Procedure. Leaching results indicate that divalent cadmium, in hydroxide or nitrate form, was contained in the cement matrix. Divalent lead was not found to be readily contained as indicated by the large amounts of lead leached. Approximately all of the divalent cadmium was immobilized by the addition of cement after a 1-day cure time, whereas a considerable amount of divalent lead was still left in a leachable form after 28 days **[1], [2]**.

79. Factors for Selecting Appropriate Solidification/Stabilization Methods

Weitzman, L. 1990. *Journal of Hazardous Materials.* 24:457-468.

This paper presents information that can be used to select solidification/stabilization methods for treating a given waste. It also discusses binders, including: Portland cement; cement kiln dust; fly ash mixtures; lime-based binders; absorbents, such as hydro and organophilic clays, wood chips, saw dust, and rice hulls; and thermoplastic materials, such as asphalt bitumen and thermoplastic polymers. Absorbents (such as sawdust or expanded clay) are generally not considered to be an acceptable method of solidifying liquids. Solidification/stabilization is generally not suitable for the stabilization of organics, although it can be used in combination with other treatment schemes which remove the organics from the waste **[2]**.

80. Feasibility of Using a Mixture of an Electroplating Sludge and a Calcium Carbonate Sludge as a Binder for Sludge Solidification

Yang, G.C.C., and K.L. Kao. 1994. *Journal of Hazardous Materials.* 36:81-88.

In this work, two industrial wastes, an electroplating sludge and a water purification calcium carbonate sludge, were obtained, mixed, and heated at 1,000° C for 4 hours. The resulting material was then tested to determine whether it could be used as a binding material to solidify the original electroplating sludge. The heat-treated sludge mixture did exhibit binding capability in a cement-based solidification of its original electroplating sludge. In this study, a modified Taguchi method was employed for the experimental design of solidification. The heat-treated sludge mixture was used to partially replace the Type I Portland cement as a binding material up to 40 weight percent. The solidified monoliths were then tested to determine their unconfined compressive strengths, Toxicity Characteristic Leaching Procedure (TCLP) toxicity, and long-term chemical durability, using the Multiple TCLP. Experimental results were found to be satisfactory. The concepts of "wastes treating wastes" and resource recycling are thus realized **[1], [2]**.

81. Fundamental Aspects of Cement Solidification and Stabilization

Roy, A., and F.K. Cartledge. 1997. Editors. *Journal of Hazardous Materials.* 52:151-354.

This special issue of the Journal of Hazardous Materials is dedicated to peer-reviewed publications on recent research findings in the advancement of solidification and stabilization technologies that incorporate cement binders. Various parts of the community involved in solidification/stabilization research are well represented in the issue, which includes articles from academia, industry, and government laboratories. The work reported in this volume shows the importance of a multidisciplinary approach in dealing with complex problems. The topics also include a number of specific problems, such as long-term matrix changes, that have often been suggested to be important but are seldom investigated in practice **[1], [2], [4]**.

82. Immobilization Mechanisms in Solidification/Stabilization of Cadmium and Lead Salts Using Portland Cement Fixing Agents

Cartledge, F.K., and S.L. Yang. 1990. *Environmental Science and Technology.* 24:867-873.

This study investigates the behavior of cadmium and lead salts toward cement-based solidification using the Toxicity Characteristic Leaching Procedure, conduction, calorimetry, and solid-state nuclear magnetic resonance as a function of time. Even though cadmium hydroxides and lead hydroxides have comparable, and very low solubilities, the situation with respect to cement solidification of aqueous sludges produced by lime treatment of solutions containing divalent cadmium and lead was found to be quite different. Concentrations of cadmium in the leachates were very low, while lead concentrations were considerably higher and would represent a serious threat to groundwater. Explanations are presented for these differences **[1], [2]**.

83. Immobilization of Chromium in Cement Matrices

Kindness, A., and others. 1994. *Waste Management.* 14:3-11.

One of the encouraging features of this study has been the ability to isolate the solubility controlling mechanisms of solidification/stabilization treatment processes. The physical potential of cements to immobilize relatively soluble chromium waste species is complemented by a chemical potential. The nature of the chemical potential varies with concentration, time, and chromium specification. Conditions favorable for retaining chromium in cement are characterized by the available alumina to form calcium aluminate hosts and by the chemical reducing conditions to stabilize trivalent chromium and reduce hexavalent chromium to the less soluble trivalent species. Slag cement blends performed well because they meet both criteria. Other combinations, such as Portland cement with an appropriate reducing agent as well as other alumina sources, such as class F fly ash, are also thought to perform well **[1], [2]**.

84. Immobilization of Zinc and Lead From Wastes Using Simple and Fiber-Reinforced Lime Pozzolana Admixtures

Debroy, M., and S.S. Dara. 1994. *Journal of Environmental Science and Health.* A29:339-355.

This study evaluates the immobilization of zinc and lead present in waste sludges by chemical fixation and encapsulation methods using lime pozzolana and fiber-reinforced lime-pozzolana admixtures. In addition, the report explains fixation and encapsulation techniques. Fixation and coating with sodium silicate solution produced good results for immobilizing lead and zinc ions, but encapsulation of heavy metal hydroxide sludge in simple and fiber-reinforced lime-fly ash mixtures was more efficient. Fiber additives to the admixture may increase the structural strength of the monolith. Coating of an encapsulated admixture may provide an additional immobilization barrier. The implications of these results for long-term storage of hazardous wastes are discussed **[1], [2], [4]**.

85. Immobilization Science of Cement Systems

Macphee, D.E., and F.P. Glasser. 1993. *MRS Bulletin*. 3:66-71.

This article highlights recent uses of cements in solidification/stabilization treatment processes and summarizes results of studies in the interactions of specific waste species and cement systems. Various aspects of waste species-cement interactions are reviewed and discussed. The differing chemistry of the elements induces a wide range of reactions, and with few exceptions, each element presents a separate challenge. Moreover, the nature of the reaction products is largely time-dependent. Satisfactory leaching methods developed for metals and glass are not applicable to cements without some reservations. The development and interpretation of leach tests are worthy of attention in order to match the material science with legislative requirements **[1], [2], [4]**.

86. Impact of Carbon Dioxide on the Immobilization Potential of Cemented Wastes: Chromium

Macias, A., and others. 1997. *Cement and Concrete Research.* 27:215-225.

In this paper the effect of carbonation on the immobilization of trivalent and hexavalent chromium has been studied in both Portland cements and blended cements containing granulated, glassy, blast furnace slag. Carbon dioxide attack, or carbonation, is the most common form of concrete environmental attack, and it promotes changes to the cement chemical composition and physical properties that can affect the durability and long-term retention of heavy metals. The results show that blends of ordinary Portland cement (Type I) and blast furnace slag are more suitable matrices for chromium-containing waste and are capable of maintaining chromium pore fluid contents below 1 part per million (ppm), even in a completely carbonated state. Slag, by virtue of its slow hydration, continues to release sulfur ions that inhibit any tendency of chromium to oxidize to hexavalent chromium. The development of a zonal structure, with separate chromium-rich and chromium-poor zones, with overall depletion of chromium from the near-surface layers of carbonated but unleached samples, requires further study. This affects carbonation rates and will have implications for the modeling of chromium leaching from matrices **[2], [3], [4]**.

87. Leachability of Lead from Solidified Cement-Fly Ash Binders

Wang, S.Y., and C. Vipulanandan. 1996. *Cement and Concrete Research*. 26:895-905.

The potential of partially replacing cement with class C fly ash to immobilize lead was investigated. Lead nitrate up to a concentration of 10 percent (by weight of binder) was solidified with Type I Portland cement and a cement-fly ash (equal proportion) mixture. Addition of fly ash to cement reduced the initial and final setting times, but with the addition of lead nitrate, setting times were increased. The compressive strength of the solidified cement decreased with the addition of fly ash and lead nitrate. Lead leachability from the solidified binder matrix was studied using the Toxicity Characteristic Leaching Procedure. The quantity of divalent lead leached depended on the initial lead nitrate concentration and the binder systems adopted. Lead solidified with cement-fly ash mixture showed slightly less leaching compared to the cement binder **[1], [2]**.

88. Long-Term Behaviour of Toxic Metals in Stabilized Steel Foundry Dusts

Andres, A., I. Ortiz, and others. 1995. *Journal of Hazardous Materials.* 40:31-42.

This study examines the long-term behavior of stabilized steel foundry dust wastes using a dynamic leach test. Two solidified and stabilized waste forms containing lead, chromium, cadmium, and zinc were produced using either cement or cement and anhydrite (waste material) as binders. The results of the dynamic leaching test were fitted to a semiempirical mathematical model based on simple leaching rate mechanisms, which permitted the evaluation of an apparent diffusion coefficient and a leachability index; these in turn provided a measure of the contaminants' mobility in the solidified waste. In the case of lead and zinc, the rate of leaching was controlled by either an initial resistance or an initial wash off, followed by diffusion of the metallic contaminants. The leaching indices obtained in both cases were higher than 12, suggesting that both solidification/stabilization processes are acceptable **[1], [2], [4]**.

89. Long-Term Leaching of Metals from Concrete Products

Webster, M.T., and R. C. Loehr. 1996. *Journal of Environmental Engineering*. 22:714-721.

The long-term leaching of metals from concrete products made with spent abrasive media was investigated using a sequential procedure that employed both an acidic extraction fluid and seawater. By using seawater, leaching behavior could be determined under conditions encountered in the environment (especially coastal areas). Chromium, cadmium, and lead concentrations were substantially less for the seawater sequential extractions than for the acidic sequential extractions. The environment created during the acidic sequential extractions resulted in the leaching of substantial amounts of alkalinity from the concrete, and leachate pH levels dropped below 4 where metals are highly soluble. The integrity of the calcium matrix within the concrete seemed to play an important role in the successful stabilization of cadmium and lead **[1], [2], [4]**.

90. Long-Term Stability of Superplasticized Monoliths of a Solidified Electroplating Sludge

Yang, G.C.C., and C.F. Chang. 1994. *Journal of Hazardous Materials.* 37:277-283.

In this work, physicochemical durability of superplasticized monoliths, solidified from an electroplating sludge, were investigated. Two categories of superplasticizer; modified lignosulphonates and sulphonated naphthalene formaldehyde condensates, were employed in this study. Each was used as an auxiliary binding agent or as a modifier to ordinary Portland cement, which was the major binder for solidification. The solidified monoliths were then subjected to various physical and chemical tests, including unconfined compressive strength (UCS); leaching toxicity by the TCLP method; physical durability by freeze/thaw and wet/dry tests; and chemical durability by the multiple TCLP test. Results show that superplasticized, solidified monoliths outperformed the corresponding control monoliths (without addition of any superplasticizer) in terms of various physical and chemical properties. Generally, the performance of both superplasticizers was found to be comparable in this study. Physical durability testing resulted in less than 1 percent of corrected, cumulative weight loss for the solidified monoliths modified by any type of superplasticizer. However, results of UCS measurements have shown that these same solidified specimens have deteriorated to some degree after the physical weathering tests. As for the resistance of solidified monoliths against the leaching of contaminants due to repetitive precipitation of a synthetic acid rain, multiple TCLP test results indicate that using either superplasticizer is satisfactory **[1], [2]**.

91. Metals Distribution in Solidified/Stabilized Waste Forms After Leaching

Cheng, K.Y., and P. Bishop. 1992. *Hazardous Waste and Hazardous Materials*. 9:163-171.

This study examines the morphology, physical structure, and metal compositions of leached cement-based waste forms using various testing procedures. A series of leach tests were conducted in the laboratory. After a sample had been leached for a given period of time, the leached surface layer was physically separated from the remaining portion of the cement-based waste form. The metal contents of the surface layer and the remaining unleached waste form were examined individually. Data generated from this research is useful in understanding the fate and transport of metal contaminants leaching out of solidification/stabilization waste forms. In addition, the metal distribution information is crucial in determining appropriate models used to predict metal leaching behavior **[1]**.

92. Ordinary Portland Cement Based Solidification of Toxic Wastes: The Role of OPC Reviewed

Hills, C.D., and others. 1993. *Cement and Concrete Research.* 23:196-212.

The work presented here is part of a wider study of the use of ordinary Portland cement (OPC) solidification technology. One common concern in the waste management industry is the vulnerability of OPC hydration to specific waste components. For this study, a mixed waste stream was solidified in the laboratory using OPC and fly ash in a variety of proportions. The solidified products were subjected to calorimetric, physical, and microstructural analyses. The heat of hydration for OPC and waste mixtures showed that a progressive poisoning of normal hydration reactions occurred with increasing concentrations of waste. Once poisoned, OPC failed to act as a cement and was substituted for with fly ash and other products. Strength development was found to be related to the heat of hydration, suggesting that conduction calorimetry could be used to determine the suitability of a particular waste for OPC-based solidification **[1]**.

93. Portland Cement Gives Concrete Support to Solidification/Stabilization

Wilk, C.M. 1995. *Environmental Solutions*. May.

This report summarizes the role of Portland cement in the solidification/stabilization of hazardous wastes and discusses the general binding mechanisms of cement components. Although Portland cement chemistry favors solidification/stabilization processes for inorganic wastes compounds, the principles of cement-based solidification/stabilization of organic wastes also are discussed. In addition, solidification/stabilization performance criteria for the individual priority metals are reviewed, including arsenic, barium, cadmium, chromium, lead, mercury, selenium, and silver, as well as copper, nickel, and zinc **[1], [2]**.

94. Potential Application of Ettringite Generating Systems for Hazardous Waste Stabilization

Albino, V., and others. 1996. *Journal of Hazardous Materials.* 51:241-252.

The advantages of ettringite-based stabilization systems over traditional cement-based ones are presented. The potential of ettringite generating systems in hazardous waste stabilization processes is also studied by means of a mixture of anhydrous calcium sulphoaluminate (ettringite) and anhydrite doped with the nitrates, and six heavy metals including, cadmium, chromium, copper, iron, lead, and zinc. The presence of metals has only a small negative effect on the hydration kinetics. The hydrated samples retain their structural integrity when submitted to the dynamic leaching test in water and in pH 4 nitric acid solution; however, they disintegrated when the leachant is a pH 4.74 acetate buffer. The ettringite can partially accommodate any metal in the crystal lattice, thus giving rise to chemical entrapment **[1], [2]**.

95. Preliminary Investigation into the Effects of Carbonation on Cement-Solidified Hazardous Wastes

Lange, L.C., and others. 1996. *Environmental Science Technology.* 30:25-30.

This paper reports results from preliminary investigations into the effects of carbonation on cement-solidified waste material. The waste, which was a commercially blended product, was solidified using different amounts of ordinary Portland cement (Type I) and cured in three different environments: nitrogen, air, and carbon dioxide. After 28 days, the samples were investigated for leachate metals fixation, strength, and microstructural development. Carbonation solidified products were characterized by enhanced calcite contents, higher strength values, and a significant reduction in leachable metals extracted compared to air-cured samples. Samples cured under a nitrogen atmosphere showed significant retardation of hydration, resulting in low strength values but improved fixation of leachable metals **[1]**.

96. Reaction of CO_2 With Alkaline Solid Wastes to Reduce Contaminant Mobility

Reddy, K.J., and others. 1996. *Water Research.* 28:1377-1382.

This study evaluates the effects of carbon dioxide treatment on the pH and soluble concentrations of inorganic contaminants in alkaline fly ash and spent shale solid wastes. A two-level (low and high), three variable (moisture, time, and pressure) statistical experiment was used to determine optimum carbon dioxide conditions. Treated and untreated samples were subjected to solubility and X-ray diffraction studies. Carbon dioxide treatment conditions of 40 pounds per square inch of pressure, 20 percent moisture, and 120 hours effectively precipitated calcite. These conditions lowered the pH and leachable concentrations of certain inorganic contaminants, including cadmium, lead, zinc, manganese, arsenic, and selenium in alkaline fly ash and spent shale samples. The results suggest that reaction with carbon dioxide under slightly elevated pressures is an effective means of reducing the soluble concentrations of certain inorganic contaminants in alkaline solid wastes, which would prevent their migration from disposal environments into groundwater **[1], [2]**.

97. Recent Findings on Immobilization of Organics as Measured by Total Constituent Analysis

Conner, J.R. 1995. *Waste Management.* 15:359-470.

New hazardous waste stabilization additives and formulations are tested to help waste managers meet the new EPA total constituent analysis regulatory requirements. The findings evaluate four cement-based formulations applied to soils containing 50 hazardous organic compounds. Two proprietary rubber particulate additives were superior relative to carbon organoclay for stabilization of most constituents. Any of the four additives or their combinations may prove valuable in immobilizing specific constituents **[1], [2]**.

98. Soil Stabilization Provides In-Situ Toxic Containment

Bornstein, R. and Wehr, F. (1991). *California Builder and Engineers*. CB&E: 35-36.

This article describes the in situ stabilization of contaminated material at a commercial burning yard in Rosamond, CA. Included in the article is a discussion of EPA laboratory tests to determine the best mixture for the soil stabilization, the technique used to excavate and stabilize the waste, and the results of analysis to determine whether EPA specifications were met. Project results showed that soil mixture strength, durability, and permeability met or exceeded the EPA specifications **[1], [2]**.

99 Solidification/Stabilization of a Heavy Metal Sludge by a Portland Cement/Fly Ash Binding Mixture

Roy, A., H.C. Eaton, and others. 1991. *Hazardous Waste and Hazardous Materials.* 8:33-41.

This paper is another in a series of studies of microchemical mechanisms involved in solidification/stabilization. A Portland cement/class F fly ash binder was used to solidify a heavy metal sludge containing cadmium, chromium, mercury, and nickel. Results indicate a wide variability in the composition of partially dewatered sludges. Such variability can lead to localized differences in the chemical composition of the solidified material. Microanalyses of the cement and fly ash mixtures indicate that fly ash spheres reacted with the Portland cement component to form a variety of reaction products, including ettringite. The results show that the sludge had an effect on cementing reactions, and it inhibited the rate and extent of hydration. To a minor degree, fly ash was involved in the chemical entrapment of the waste elements **[1], [2]**.

100. Solidification/Stabilization of Arsenic: Effects of Arsenic Specification

Buechler, P., and others. 1996. *Journal of Environmental Science and Health.* A31:747-754.

This study evaluates the chemical identity of arsenic compounds subjected to solidification/ stabilization in determining eventual leachability from the treated material. Arsenic compounds have major effects on the developing cement matrix when Portland cement is the binder. Of the compounds studied, the organoarsenic species, arsanilic acid, has the least effect on the formation of the hydrated cement matrix, but it shows the greatest Toxicity Characteristic Leaching Procedure effects. Arsenic trioxide has the greatest effect on the matrix, reducing the hydration from 70 to 40 percent at 28 days of cure. Arsenate and arsenite salts have intermediate effects on matrix formation, but they show low leachabilities. An organoarsenic fungicide waste treated with Portland cement alone showed significant leachability, but leachability was greatly reduced in the presence of tetramethylammonium bentonite **[1], [2]**.

101. Solidification/Stabilization of Hazardous Waste: Evidence of Physical Encapsulation

Roy, A., and others. 1992. *Environmental Science and Technology.* 26:1349-1353.

The nature of a synthetic electroplating sludge (EPA waste classification F006) containing cadmium, chromium, mercury, and nickel, as well as its solidification/stabilization mechanisms were evaluated by investigating the microscopic morphologies and microchemistry of the solidified and stabilized products. The sludge consisted of impure, submicrometer-sized crystallites of heavy metal salts that retarded hydration of the ordinary Portland cement (Type I). However, the hydration products were the same as those formed in the absence of the sludge. Morphologies observed in the ordinary Portland cement/sludge samples were distinctly different from those normally observed in hardened cement. Physical encapsulation on a microscopic scale was the principal mechanism of stabilization **[1], [2]**.

102. Solidification/Stabilization of Heavy Metals in Latex Modified Portland Cement Matrices

Daniali, S. 1990. *Journal of Hazardous Materials.* 24:225-230.

This paper presents preliminary research data to develop latex-modified cement systems for the solidification/stabilization of inorganic wastes containing lead and chromium. Polymers have long been used to improve the properties of concrete and cement mortar, especially when these materials are subjected to severe chemical attack. Results of freeze/thaw durability tests conducted on the synthetic wastes show little or no weight loss after 50 cycles. In addition, unconfined compressive strength tests show no loss of strength due to the presence of lead and chromium. Preliminary Toxicity Characteristic Leaching Procedure and extraction procedure tests indicate considerable improvement over regular Portland cement **[1], [2], [3]**.

103. Stabilization and Solidification of Lead in Contaminated Soils

Lin. S.L., and others. 1996. *Journal of Hazardous Materials*. 48:95-110.

In this study, a sulfur waste material was employed as a binder to stabilize and solidify lead-contaminated soils. Soil samples collected from a battery recovery plant had high levels of inorganic lead. Results obtained from the study indicated that sulfur binders can be used to solidify and stabilize inorganic lead-contaminated soil, which may or may not contain organic compounds. However, control samples, which used Portland cement to solidify the same contaminated soils, showed that Portland cement was also an effective binder. The potential applications of these solidified matrixes also are discussed. Due to the excellent physical, engineering, and chemical leaching characteristics, sulfur-solidified wastes could be used as construction fills, such as road fill in pavement construction. Under some circumstances, use of the sulfur stabilization/solidification process will be a viable choice, especially where excess sulfur, recovered from various industrial desulfurization sites, becomes a waste product that requires disposal. The excess waste (sulfur) can be used as a stabilization agent to treat lead-contaminated soil locally. Thus the two waste materials can be combined and converted into an environmentally stable material for recycling without having to be deposited in a landfill site **[1], [2]**.

104. The Binding Chemistry and Leaching Mechanisms of Hazardous Substances in Cementitious Solidification/Stabilization Systems

Cocke, D.L. 1990. *Journal of Hazardous Materials*. 24:231-253.

The aim of this work is to provide information for (1) the design of new or improved solidification/stabilization systems and (2) mathematically modeling the leaching. The chemistry of binding and the mechanisms of leaching of hazardous substances, particularly priority heavy metal pollutants, in cementitious systems are discussed in terms of their bulk and surface states. Particular attention is given to the nature of the surface and solution chemistries. Key to understanding the binding and leaching processes in cement is the characterization of the chemical and physical states involved. Recent efforts in the surface bulk and morphological characterization of solidification/stabilization hazardous metal-Portland cement systems are presented, with the results summarized in physical and chemical concepts **[1], [2]**.

105. The Effects of Simulated Environmental Attack on Immobilization of Heavy Metals Doped in Cement-Based Materials

Bonen, D., and S.L. Sarkar. 1995. *Journal of Hazardous Materials.* 40:321-335.

This study investigates the effects of long-term simulated corrosive environmental conditions for the leaching characteristics of selected heavy-metal oxides stabilized in Portland cement as well as the leaching from paste and mortar. Portland cement-based materials, which are often used as binders for hazardous waste immobilization, are prone to various types of chemical attack, including corrosion by soft water and ground water. Carbon dioxide-bearing water is most deleterious, affecting the leachability characteristics of waste-based cement over time. Heavy metals analyzed include cadmium, nickel, lead, and mercury. Results from aggressive carbon dioxide attack indicated the formation of a peripheral decalcified zone (the leached zone) and an apparent intact unleached zone. The leached zone was characterized by a depleted heavy metal content, in which nickel and cadmium were converted into hydroxides, and mercury remained in its original oxide form. The leaching rate of the metals was lowest for lead and increased for nickel and cadmium. Increasing the metal load increased the amount of metals leached at any given time **[1], [2], [3], [4]**.

106. The History of Stabilization/Solidification Technology

Conner, J.R. and Hoeffner, S.L. 1998. *Critical Reviews in Environmental Science and Technology*. 28(4): 325-396.

This article describes the history of solidification/stabilization. The processes and techniques of solidification/stabilization have matured into an accepted and important part of environmental technology. How it came about is presented in both an interesting and instructive way. The article includes a definition of terms; overview of the basics of solidification/stabilization technology; a discussion of the origins of solidification/stabilization before 1970, its pre-RCRA use (1970-1976), the post-RCRA solidification/stabilization industry (1976-1990), the current solidification/stabilization technology (1990 to present), and the future of solidification/stabilization **[1], [2]**.

107. The Interfacial Chemistry of Solidification/Stabilization of Metals

Mollah, Y.M.A., and others. 1995. *Waste Management.* 15:137-148.

This study investigates the chemistry of cement, its hydration, and mechanisms of solidification/stabilization of toxic metals by cement-based systems, near surface, and interfacial phenomena. The adsorption conditions and the selectively strong affinity of hazardous metals towards clay minerals, certain hydrated metal oxides and oxyhydroxides, and cementitious substances also play an important role in the solidification/stabilization process for the immobilization of contaminants. Recent work involving metal ions and superplasticizers have elucidated the mechanics of reactions that retard cement hydration and subsequent setting as well as their interactions with silicate-based systems. This paper delineates the current status of interfacial chemistry at the solid-liquid boundary and places it in perspective with present and future solidification/ stabilization processes based on Portland cement and pozzolanic materials. The importance of surface charge, the role of interfacial phenomena on adsorption, and the importance of calcium and other types of anions and cations in solidification/stabilization are also discussed. A surface charge control reaction model that accounts for the importance of calcium and other cations and anions is outlined and is used to discuss the chemical nature and microstructure of the interfacial transition zone **[1], [2]**.

Topics Addressed:

[1]	Performance Evaluation or Testing Protocols
[2]	Contaminant- or Waste-Specific Procedures
[3]	Durability and Degradation
[4]	Long-term Effectiveness

108. The Limitation of the Toxicity Characteristic Leaching Procedure for Evaluating Cement-Based Stabilized/Solidified Waste Forms

Poon, C.S., and K.W. Lio. 1997. *Waste Management*. 17:15-23.

The EPA Toxicity Characteristic Leaching Procedure (TCLP) is commonly used as a regulatory tool to determine whether or not a waste can be classified as a hazardous waste. The validity of the test procedure for assessing cement-based stabilized and solidified heavy metal wastes is examined in this paper. Synthetic cement-based heavy metal waste forms with different acid neutralizing capacity were prepared and subjected to TCLP to study the effect of waste acid neutralizing capacity metal leaching. A real waste was also obtained from a local commercial treatment facility and tested to verify the findings. The results showed that as long as the stabilized and solidified waste forms neutralize the acidity of the leachant, the leaching of metals will be small, and the performance of the different waste forms cannot be differentiated. The test therefore has limited use in comparing the performance of different cement-based waste forms. A modified test procedure is proposed **[1]**.

109. Time Effects of Three Contaminants on the Durability and Permeability of a Solidified Sand

Al'Tabbaa, A., and S.D. King. 1998. *Environmental Technology.* 19:401-407.

This paper examines the effect of three contaminants in low and high concentrations on the durability (wet/dry and freeze/thaw) and permeability of stabilized and solidified contaminated sand. The effect was investigated in terms of the development of the two properties with time under the influence of the contaminants after two curing periods results provide some insight into the development of the behaviour with time. The results show that in some cases the behaviour depends not only on the type of the contaminant, but also on its concentration. In general, both the durability (as measured by wet/dry and freeze/thaw tests) and permeability results improved with time as the curing period increased from 28 to 56 days. These results were attributed to the continual hydration of cement. This means that the design of solidified and stabilized soil is based on 28-day durability, and permeability would lead to an uneconomical design unless the effect of continual hydration of the cement products, and hence continual development of the two properties, is allowed for in some way. This emphasizes the need to develop appropriate tests that model in situ long-term behavior of solidified and stabilized ground **[1], [3], [4]**.

110. Treatment of Metal Industrial Wastewater by Flyash and Cement Fixation

Weng, C.H., and C.P. Huang. 1994. *Journal of Environmental Engineering.* 120:1470-1488.

This paper presents a technique for treating industrial waste waters contaminated with heavy metals. The proposed method employs fly ash adsorption and cement fixation of the metal-contaminated adsorbent compound to isolate the metals. Fly ash can provide an acceptable level of metal adsorption for zinc and cadmium in dilute wastewater streams with adsorption capacities of 0.27 and 0.05 milograms per gram, respectively. Tests of leachates derived from the fixed metal-laden fly ash indicated that concentrations of the metals in the leachates were lower than the existing drinking water standards **[1], [2]**.

111. Variability of Field Solidified Waste

Stegemann, J.A., Caldwell, R.J. and Shi, C. 1997. *Journal of Hazardous Materials*. 52: 335-348.

There is little information available regarding the effect of field variability on solidified waste properties. In a field test conducted by the Wastewater Technology Centre it was found that the proportions of the waste (electric arc furnace dust) and binder (activated blast furnace slag) could be controlled within 2 percent, expressed as a fraction of the mix. Comparisons of comprehensive physical and chemical test results for laboratory and field solidified specimens of electric arc furnace dust showed that the physical properties of the field solidified material were sensitive to changes in water addition. Chemical properties and leachability were most affected by changes in pH and acid neutralization capacity. However, both physical and chemical properties remained within the desired range **[1], [2], [3], [4]**.

BIBLIOGRAPHIES

112. Hazardous Wastes - Fixation, Solidification, and Vitrification Excluding Radioactive Materials

Energy Science and Technology Database. 1998. U.S. Department of Energy, Washington, DC.

NTIS Document No.: PB96-855945INI
http://www.ntis.gov

This bibliography contains the latest citations concerning the fixation or solidification of hazardous wastes. Articles discuss methods of fixation, such as use of cements, concretes, silicates, fly ash, and vitrified glass. Citations are continuously updated to examine the ability of various techniques to immobilize hazardous materials; immobilization is determined by leach tests and experimental verification. Materials discussed include furnace wastes, contaminated soils, sludges, asbestos wastes, organic wastes, and ashes. The bibliography contains as many as 250 citations and includes a subject term index and title list **[1], [2]**.

113. Radioactive Waste Processing - Fixation in Cements and Bitumens

Energy Science and Technology Database. 1998. U.S. Department of Energy, Washington, DC.

NTIS Document No.: PB96-855135INI
http://www.ntis.gov

This bibliography contains citations concerning the fixation or solidification of radioactive wastes using cements, bitumens, or asphalts. Formulation, physical strength, degradation, and leachability of these materials is presented. Specific full-scale production plants are described. Wastes that can be contained through fixation include gaseous wastes, nitrate salts, borate salts,

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Topics Addressed:
[1] Performance Evaluation or Testing Protocols
[2] Contaminant- or Waste-Specific Procedures
[3] Durability and Degradation
[4] Long-term Effectiveness

spent fuels, contaminated soils, sludges, and liquid wastes. The bibliography contains about 250 citations and includes a subject term index and title list **[1], [2]**.

IN SITU SOLIDIFICATION/STABILIZATION RESOURCES

114. Engineering Issue: Considerations in Deciding to Treat Contaminated Soils In Situ

U.S. Environmental Protection Agency. 1993. Office of Solid Waste and Emergency Response. Washington, DC.

EPA Document No.: EPA/540/S-94/500
NTIS Document No.: PB94-177771/XAB

The purpose of this document is to assist in deciding whether consideration of in situ treatment of contaminated soil is worthwhile and to assist in the selection and review of in situ technologies. This document addresses issues associated with assessing the feasibility of in situ treatment and selecting appropriate in situ technologies, including characteristics of the contaminants, the site, the technologies, and how these factors and conditions interact to allow for effective delivery, control, and recovery of treatment agents and contaminants. The document focuses on established and innovative in situ treatment technologies already available or available for full-scale application within 2 years, including in situ solidification/stabilization. The document is intended to assist in identifying applicable alternatives early in the technology screening process and is not a source for final determinations **[1], [2]**.

115. Handbook on In Situ Treatment of Hazardous Waste-Contaminated Soils

U.S. Environmental Protection Agency. 1990. Risk Reduction Engineering Laboratory. Office of Research and Development. Cincinnati, OH.

EPA Document No.: EPA/540/2-90/002
NTIS Document No.: PB90-155607/XAB

This publication discusses various alternatives for in situ treatment of hazardous waste in contaminated soils. Several in situ technologies are described, including in situ solidification/stabilization treatment processes. Delivery and recovery systems also are discussed. The document includes a description of the treatment process and its advantages and disadvantages. An extensive list of references is included **[1], [2]**.

Topics Addressed:

[1]	Performance Evaluation or Testing Protocols
[2]	Contaminant- or Waste-Specific Procedures
[3]	Durability and Degradation
[4]	Long-term Effectiveness

116. International Waste Technologies/Geo-Con In Situ Stabilization/Solidification: Applications Analysis Report

U.S. Environmental Protection Agency. 1996. Risk Reduction Engineering Laboratory. Office of Research and Development. Cincinnati, OH.

EPA Document No.: EPA/540/A5-89/004
NTIS Document No: PB-90-269085

This Application Analysis Report evaluates (1) the International Waste Technologies HWT-20 additive and the Geo-Con, Inc., deep-soil-mixing equipment for an in situ stabilization/ solidification process and (2) its applicability as an on-site treatment method for waste site cleanup. The in situ treatment technology demonstration was conducted under EPA's Superfund Innovative Technology Evaluation Program in April 1988, at the General Electric Company electric service shop in Hialeah, Florida. Soil at the site contained polychlorinated biphenyls and localized concentrations of volatile organics and heavy metal concentrations. This report discusses the in situ process based on test results of the demonstration, as well as other data provided by the technology developer and the general capabilities of cement-based systems. It also discusses the probable applicability of the technology to sites other than the General Electric Company electric service shop **[1], [2]**.

117. Overview of In Situ Waste Treatment Technologies

Hyde, R.A., and others. 1992. EG&G Idaho, Inc. Idaho Falls, ID.

NTIS Document No.: DE92-018012/XAB

In situ technologies are an attractive remedial alternative when addressing environmental problems, and they typically reduce risks and costs associated with retrieving, packaging, and storing or disposing of wastes. Each in situ technology has specific applications; to provide the most economical and practical solution to a waste problem, these applications must be understood. This paper presents an overview of 30 in situ remedial technologies for buried wastes or contaminated soil areas. The objective of this paper is to familiarize those involved in waste remediation activities with available and emerging in situ technologies so that they may consider these options in the remediation of hazardous and radioactive waste sites. Several types of in situ technologies are discussed, including solidification/stabilization. Much of the information on in situ treatment technologies was obtained directly from vendors and universities, and this information has not been verified **[2]**.

118. Pilot In Situ Auger Mixing Treatment of a Contaminated Site - Part I: Treatability Study

Al'Tabbaa, A., and C.W. Evans. 1998. *Geotechnical Engineering*. 131:52-59.

The work presented in this two-part publication covers certain findings of a research contract and related studies to develop an in situ stabilization/solidification treatment methodology using auger mixing at a contaminated site at West Drayton. This paper, Part 1, contains the introduction, site details, and results of the laboratory treatability study; Part 2 details the prototype auger development, site trial, and assessment of the in situ treatment. The objective of the treatability study was to develop soil-grout mixes appropriate for the site soils and in situ application process, with an emphasis on low cement and grout content. Cement-based soil-grout mixes were developed based on available strength, durability, permeability, compressibility, and leachate pH design criteria. Constituents of the soil-grout mixes, which included cement, pulverized fuel ash and lime, and their ratios were varied. Contradicting requirements for satisfying some of the criteria meant that the developed mixes had to be a compromise. The applicability of the permeability and freeze/thaw durability criteria considered for the stabilized contaminated soil was questioned **[1], [2]**.

119. Recent Developments for In Situ Treatment of Metal Contaminated Soils

U.S. Environmental Protection Agency. 1997. Technology Innovation Office. Office of Solid Waste and Emergency Response. Washington, DC.

EPA Document No.: EPA-542-R-97-004

This report provides a status update on available and promising technologies for in situ remediation of soils contaminated with heavy metals. It is intended to assist in the remedy selection process by providing information on four in situ technologies, including solidification/stabilization. The report discusses different techniques currently in practice or under development, identifies vendors and summarizes performance data, and discusses technology attributes that should be considered during early screening of potential remedies. EPA-sponsored demonstrations reviewed in the report indicate that in situ solidification/stabilization is effective in reducing leachable concentrations of metals to within regulatory or risk-based limits. Failure to meet the design specifications in the field most often stems from poor grout control, such as inconsistently formulated slurries or clogged injection ports that cause incomplete mixing or a spray pattern that is not uniform **[1], [2]**.

Topics Addressed:

[1]	Performance Evaluation or Testing Protocols
[2]	Contaminant- or Waste-Specific Procedures
[3]	Durability and Degradation
[4]	Long-term Effectiveness

120. Technology Evaluation Report: SITE Program Demonstration Test, International Waste Technologies In Situ Stabilization/Solidification, Hialeah, Florida

U.S. Environmental Protection Agency. 1989. Risk Reduction Engineering Laboratory. Office of Research and Development. Cincinnati, OH.

EPA Document No.: EPA/540/5-89/004a
NTIS Document No.: PB-89-194161

This Technology Evaluation Report evaluates the International Waste Technologies HWT-20 additive and the Geo-Con, Inc. deep-soil-mixing equipment for an in situ stabilization/ solidification process and its applicability as an on-site treatment method for waste site cleanup. The in situ treatment technology demonstration was conducted under EPA's Superfund Innovative Technology Evaluation (SITE) Program in April 1988, at the General Electric Company electric service shop in Hialeah, Florida, where the soil contained polychlorinated biphenyls (PCBs) and localized concentrations of volatile organics and heavy metal concentrations. This report provides an interpretation of the available data and presents conclusions on the results of the demonstration, as well as the potential applicability of the technology at other sites **[1], [2]**.

SOURCES OF SOLIDIFICATION/STABILIZATION TECHNOLOGY INFORMATION/TECHNICAL ASSISTANCE

Numerous World Wide Web sites, publications/search systems, dockets, hotlines/regulatory/technical assistance centers, and library resources are available to provide information or technical assistance related to issues concerning solidification and stabilization. Many of these sources are available through EPA's main web address, www.epa.gov. This web site provides access to a variety of EPA offices, laboratories, and regions; the reader is referred to the following EPA offices as providing information that is particularly relevant to solidification and stabilization: Office of Solid Waste and Emergency Response (OSWER), Office of Emergency and Remedial Response (OERR), Office of Solid Waste (OSW), and Office of Research and Development (ORD). Specific sources of information are identified below, with information about how to access these sources.

WORLD WIDE WEB SITES:

- **Hazardous Waste Cleanup Information (CLU-IN)**
  CLU-IN provides information about innovative remediation and site characterization technologies for hazardous waste cleanup professionals. It includes information on publications and software, partnerships and consortia, regulatory items, vendor support, internet and on-line resources, and international activities.

  Help Line...............................301-589-8368
  Internet address: http://clu-in.org

- **Alternative Treatment Technologies Information Center (ATTIC)**
  ATTIC is a comprehensive computer database system that provides up-to-date information on innovative treatment technologies. ATTIC provides users with access to several independent databases, as well as a mechanism for obtaining full-text technical publications. The database contains information on biological, chemical, and physical treatment technologies; solidification and stablization technologies; and thermal treatment technologies.

  Help Line...............................513-569-7272
  Internet address: http://www.epa.gov/attic

- **Federal Remediation Technologies Roundtable (FRTR)**
  FRTR is an interagency working group that provides a forum for the exchange of information about the development and demonstration of innovative technologies for the remediation of hazardous waste sites. The forum also synthesizes the technical knowledge that federal agencies have compiled and provides a comprehensive record of performance and cost of the technologies. Participating agencies include the U.S. Department of Defense, the U.S. Department of Energy, and the U.S. Environmental Protection Agency.
  Internet address: http://www.frtr.gov

- **Remediation Technologies Development Forum (RTDF)**
  RTDF was established by the U.S. Environmental Protection Agency (EPA) to foster partnerships of public and private-sector entities that conduct laboratory and applied research to develop, test, and evaluate innovative remediation technologies. To date, seven action teams have been established by RTDF, including: the Bioremediation of Chlorinated Solvents Consortium, the LASAGNA™ Partnership, the Permeable Reactive Barriers Action Team, the Sediments Remediation Action Team, the In-Place Inactivation and Natural Ecological Restoration Technologies (IINERT) Soil-Metals Action Team, the Phytoremediation of Organics Action Team, and the In Situ Flushing Action Team.
  Internet address: http://www.rtdf.org

- **Superfund Innovative Technology Evaluation (SITE) Demonstration Program**
  The SITE program was established by EPA's Office of Solid Waste and Emergency Response (OSWER) and the Office of Research and Development (ORD) to encourage the development and implementation of innovative treatment technologies for the remediation of hazardous waste sites and for monitoring and measurement technologies. Through the program, technologies are field-tested and engineering and cost data are gathered.
  Internet address:
  http://www.epa.gov/ORD/SITE

SOURCES OF SOLIDIFICATION/STABILIZATION TECHNOLOGY INFORMATION/TECHNICAL ASSISTANCE (CONT'D)

PUBLICATIONS/SEARCH SYSTEMS:

- **Site Remediation Technology InfoBase***:*
  A Guide to Federal Programs, Information Resources, and Publications on Contaminated Site Cleanup Technologies (EPA/542/B-98/006; August 1998)

  This publication was prepared under the auspices of the Federal Remediation Technologies Roundtable and summarizes information about federal cleanup programs within the U.S. DoD, U.S. DOE, and EPA; site remediation technology development assistance programs; site remediation technology development electronic databases; and electronic resources for site remediation technology information. It also provides a selected bibliography of publications and identifies technology program contacts.

- **DIALOG Database............800-3-DIALOG**
  Contains files relevant to hazardous waste including: Enviroline, CA Search, Pollution Abstracts, Compendex, Energy Science and Technology, National Technical Information Service (NTIS), and others.
  Internet address: http://www.dialog.com

DOCKETS:

- **Federal Agency Hazardous Waste Compliance Docket Hotline 800-548-1016**
  Provides the name, address, NPL status, agency, and Region for the Federal facilities listed on the Federal Agency Hazardous Waste Compliance Docket. Facilities are on the docket because they reported being a RCRA TSDF or having spilled or having the potential to release CERCLA hazardous waste. Operates Monday - Friday 8:00 a.m.- 6:00 p.m., Eastern Time.

- **UST Docket...........................703-603-9230**
  Provides documents and regulatory information pertinent to RCRA Subtitle 1 (the Underground Storage Tank program).
  Operates Monday - Friday, 9:00 a.m. - 4:00 p.m., Eastern Time.
  To send a request: U.S. Environmental
  Protection Agency
  Office of Underground
  Storage Tank Docket
  401 M Street, SW, 5305W
  Washington, DC 20460
  To fax a request: 703-603-9234

- **RCRA Information Center...703-603-9230**
  Indexes and provides public access to all regulatory materials supporting the Agency's actions under RCRA, and disseminates current Office of Solid Waste publications.
  Operates Monday - Friday, 9:00 a.m. - 4:00 a.m., Eastern Time.

- **Superfund Docket.................703-603-9232**
  Provides access to Superfund regulatory documents, Superfund Federal Register Notices, and RODs.
  Operates Monday - Friday, 9 a.m. - 4 p.m., Eastern Time.
  To fax a request: 703-603-9240
  email: superfund.docket@epamail.epa.gov

HOTLINES/REGULATORY/TECHNICAL ASSISTANCE:

- **RCRA/Superfund Hotline...800-424-9346, 703-412-9810, TDD: 800-553-7672, 703-412-3323**
  Provides regulatory assistance related to RCRA, CERCLA, and UST programs. Serves as a liaison between the regulated community and EPA personnel and provides information on the availability of relevant documents.
  Operates Monday - Friday, 9:00 a.m. - 6:00 p.m., Eastern Time.
  Internet address:
  http://www.epa.gov/epaoswer/hotline/

- **Superfund Health Risk Technical Support Center...................................513-569-7300**
  Provides EPA Regional Superfund risk assessors, State agencies, and those working under EPA contract with technical, typically chemical-specific, support and risk assessment review.
  Operates Monday - Friday, 8 a.m. - 5 p.m., Eastern Time.
  To fax a request: 513-569-7159

- **TSCA Hotline........................202-554-1404**
  Answers public and private regulatory questions on TSCA. Refers callers to appropriate EPA contacts, and takes TSCA-relevant document orders.
  Operates Monday - Friday, 8:30 a.m. - 5:00 p.m., Eastern Time.
  To fax a request: 202-554-5603

SOURCES OF SOLIDIFICATION/STABILIZATION TECHNOLOGY INFORMATION/TECHNICAL ASSISTANCE (CONT'D)

LIBRARIES:

- The EPA Headquarters and Regional Libraries provide information services covering a wide range of environmental and related subjects, including hazardous waste, air and water pollution and control, environmental law, solid waste, toxic substances, and test methods. These libraries also provide a collection of materials on social, economic, legislative, legal, administrative, and management projects related to all aspects of environmental policy. EPA Headquarters and Regional Libraries contact information is provided below. In addition to resources available through EPA libraries, users may also access relevant documents through university libraries or other public libraries that house government documents.

- **EPA Headquarters Library**
  Headquarters Information
  Resources Center
  To send a request: Environmental Protection Agency
  401 M Street, SW
  Mail Code 3404
  Washington , DC 20460
  Operates Monday - Friday, 8 a.m. - 5 p.m., Eastern Time.
  Phone.....................................202-260-5922
  Fax..202-260-5153
  email: library-hq@epamail.epa.gov

- **EPA Region 1 Library (Boston, MA)**
  To send a request: JFK Federal Building
  Boston, MA 02203-0001
  Operates Monday - Friday, 8:30 a.m. - 5 p.m., Eastern Time
  Phone...................................617-565-3300
  Fax.......................................617-565-9067
  e-mail: library-regl@epamail.epa.gov
  Internet address:
  http://www.epa.gov/region01/oarm/index.html

- **EPA Region 2 Library (New York, NY)**
  To send a request: 290 Broadway, 16th Floor
  New York, NY 10007
  Operates Monday - Thursday, 9 a.m. - 4:30 p.m., Friday 9 a.m. - 1 p.m., Eastern Time
  Phone.....................................212-637-3185
  Fax..212-637-3086
  e-mail: library-reg-2@epamail.epa.gov
  Internet address:
  http://www.epa.gov/Region2/library/

- **EPA Region 3 Library (Philadelphia, PA)**
  To send a request: 1650 Arch Street
  (3PM52)
  Philadelphia, PA 19103
  Operates Monday - Friday, 8 a.m. - 4 p.m., Eastern Time
  Phone.....................................215-814-5254
  Fax..215-814-5253
  e-mail: library-reg3@epamail.epa.gov
  Internet address:
  http://www.epa.gov/region3/r3lib/index.html

- **EPA Region 4 Library (Atlanta, GA)**
  To send a request: Atlanta Federal Center
  61 Forsyth St, SW
  9th Floor Tower
  Atlanta, GA 30303-3104
  Operates Monday - Friday, 8 a.m. - 4 p.m., Eastern Time
  Phone.....................................404-562-8190
  Fax..404-562-8114
  Internet address:
  http://www.epa.gov/recoreds/a00220.html

- **EPA Region 5 Library (Chicago, IL)**
  To send a request: 77 West Jackson Boulevard
  Chicago, IL 60604-3590
  Operates Monday - Friday, 7:30 p.m. - 5 p.m., Central Time
  Phone.....................................312-353-2022
  Fax..312-353-2001
  e-mail: library.reg5@epamail.epa.gov
  Internet address:
  http://www.epa.gov/region5/library/

- **EPA Region 6 Library (Dallas, TX)**
  To send a request: 1445 Ross Avenue
  Dallas, TX 75202
  Operates Monday - Friday, 7:30 a.m. - 4:30 p.m., Central Time
  Phone.....................................214-665-6424
  Fax..214-665-2714
  e-mail: library-reg6@epamail.epa.gov
  Internet address:
  http://www.epa.gov/6mol/6lib.htm

SOURCES OF SOLIDIFICATION/STABILIZATION TECHNOLOGY INFORMATION/TECHNICAL ASSISTANCE (CONT'D)

- **EPA Region 7 Library (Kansas City, KS)**
  To send a request: Information Resource Center
  726 Minnesota Avenue
  Kansas City, KS 66101-2728
  Operates Monday - Friday 10 a.m. - 3 p.m. (walk-in), 8:30 a.m. - 5 p.m. (phone), Central Time
  Phone.............................913-551-7241/7358
  Fax..913-551-7467
  e-mail: library-reg7@epamail.epa.gov
  Internet address:
  http://www.epa.gov/earth100/records/a00222.html

- **EPA Region 8 Technical Library (Denver, CO)**
  To send a request: 999 18th Street, Suite 500
  (8OC-L)
  Denver, CO 80202
  Operates Monday - Friday, (except Wednesday), 12:00 noon - 4:00 p.m., Mountain Time, operates Wednesday 10 a.m. - 4 p.m., Mountain Time
  Phone......................................303-312-6312
  Fax..303-312-7061
  e-mail: R8EISC@epamail.epa.gov
  Internet address:
  http://www.epa.gov/region08/html/eisc.html

_ **EPA Region 8 Library (Denver, CO)**
  Environmental Information Service Center (EISC)
  Phone………………………303-312-6312
  and 1-800-227-8917 (for region 8 states only)
  Fax……………………….…303-294-1087

- **EPA Region 9 Library (San Francisco, CA)**
  To send a request: 75 Hawthorne Street
  San Francisco, CA 94105
  Operates Monday - Friday, 9 a.m. - 4 p.m., Western Time
  Phone......................................415-744-1510
  Fax..415-744-1474
  e-mail: library-reg9@epamail.epa.gov
  Internet address:
  http://www.epa.gov/region09/library/

- **EPA Region 10 Library (Seattle, WA)**
  To send a request: 1200 Sixth Avenue,
  Mail code OMP-104
  Seattle, WA 98101
  Operates Monday - Friday, 9 a.m. - 4 p.m., Western Time
  Phone......................................206-553-1289
  Fax..206-553-0110
  email: library-reg10@epamail.epa.gov
  Internet address:
  http://www.epa.gov/earth100/records/a00225.html

- **RREL/Site Superfund Videotape Library**
  Provides composite videotapes containing a number of EPA produced documentaries on specific Superfund Innovative Technology Evaluation (SITE) Program demonstrations. Operates Monday - Friday, 8:30 a.m. - 4:30 p.m., Eastern time
  Phone......................................201-535-2219

OTHER RESOURCE GUIDES

The following documents are intended to support decision-making by Regional and State Corrective Action permit writers, Remedial Project Managers (RPMs), On-Scene Coordinators, contractors, and others responsible for the evaluation of innovative treatment technologies. These guides direct managers of sites being remediated under RCRA, UST, and CERCLA to bioremediation, ground water, physical/chemical, soil vapor extraction (SVE), SVE enhancement, and solidification/stabilization treatment technology resource documents; databases; hotlines; and dockets, and identify regulatory mechanisms (for example, Research Development and Demonstration Permits) that have the potential to ease the implementation of these technologies at hazardous waste sites. Collectively, the guides provide abstracts of over 400 guidance/workshop reports, program documents, studies and demonstrations, and other resource guides, as well as easy to use Resource Matrices that identify the technologies and contaminants discussed in each abstracted document. The title and document number is provided for each.

1. Bioremediation Resource Guide

U.S. Environmental Protection Agency. September, 1993. Office of Solid Waste and Emergency Response. Technology Innovation Office. Washington, DC. **[1], [2], [3]**.

EPA Document No.: EPA/542-B-93/004
NTIS Document No.: PB-94-112307

2. Ground Water Treatment Technology Resource Guide

U.S. Environmental Protection Agency. September, 1994. Office of Solid Waste and Emergency Response. Technology Innovation Office. Washington, DC. **[1], [2]**.

EPA Document No.: EPA/542-B-94/009
NTIS Document No.: PB-95-138657

3. Physical/Chemical Treatment Technology Resource Guide

U.S. Environmental Protection Agency. September, 1994. Office of Solid Waste and Emergency Response. Technology Innovation Office. Washington, DC. **[1], [2]**.

EPA Document No.: EPA/542-B-94/008
NTIS Document No.: PB-95-138665

OTHER RESOURCE GUIDES (CONT'D)

4. Soil Vapor Extraction (SVE) Enhancement Technology Resource Guide

U.S. Environmental Protection Agency. October, 1995. Office of Solid Waste and Emergency Response. Technology Innovation Office. Washington, DC. **[1], [2]**.

EPA Document No.: EPA/542-B-95/003

5. Soil Vapor Extraction (SVE) Treatment Technology Resource Guide.

U.S. Environmental Protection Agency. September, 1994. Office of Solid Waste and Emergency Response. Technology Innovation Office. Washington, DC. **[1], [2]**.

EPA Document Number: EPA/542-B-94/007
NTIS Document Number: PB-95-138681

WE WOULD LIKE YOUR COMMENTS

We would like your comments about this guide, especially on:

- Questions about solidification/stabilization technologies
- Information about solidification/stabilization technology documents that you have drafted or completed which may be suited for inclusion in an update to this Guide.

Mail this form:

- Fold the form into thirds (along the dotted lines) so that the address shows on the outside.
- Tape the form closed.
- Add a first class stamp (EPA employees use interoffice or pouch mail).
- Drop it in the mail.

or Fax this form:

TIO - (703) 603-9135 or (703) 603-9167

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