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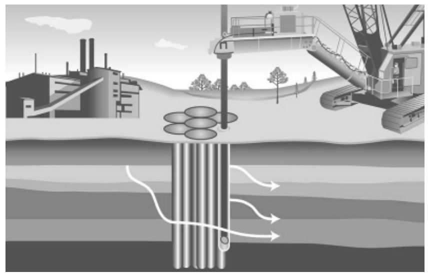
Welcome – Thanks for joining this ITRC Training Class

Solidification/Stabilization



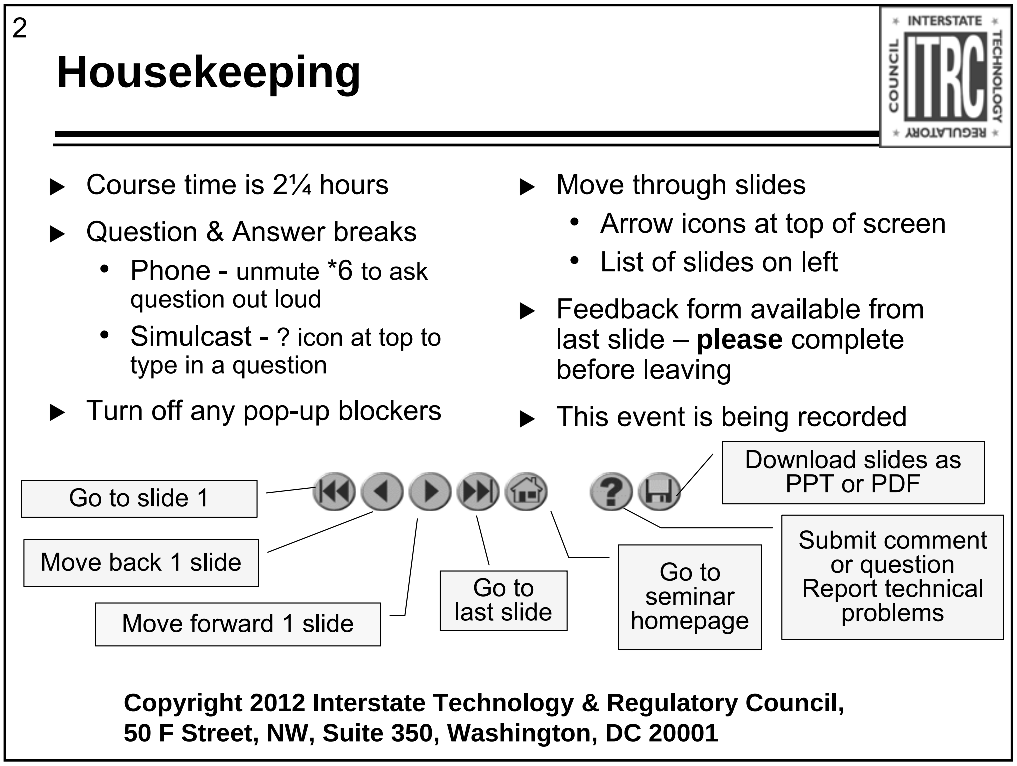
ITRC Technical And Regulatory Guidance Document: Development of Performance Specifications for Solidification/Stabilization (S/S-1, 2011)

Sponsored by: Interstate Technology and Regulatory Council (www.itrcweb.org)
Hosted by: US EPA Clean Up Information Network (www.cluin.org)

Solidification/Stabilization (S/S) is a remedial technology option which blends treatment reagents into contaminated material to impart physical and/or chemical changes to reduce the flux of contamination that leaches from a contaminant source to within acceptable parameters set forth in a site-specific remediation goal. S/S can be effective for metals, asbestos, radioactive materials, oxidizers, PAHs, PCBs, and pesticides and is potentially effective for dioxins/furans, some VOCs and other organics. Although there is abundant literature describing the S/S process and test methods for design and implementation, there was a lack of guidance for assessing performance. The ITRC technical and regulatory guidance document Development of Performance Specifications for Solidification/Stabilization (S/S-1, 2011) and associated Internet-based training provide an approach to assist practitioners and regulators with measuring and determining acceptable S/S performance. This approach developed by the ITRC Solidification/Stabilization Team provides information for developing, testing, and evaluating appropriate site-specific performance specifications and the considerations for designing appropriate long-term stewardship programs. In addition, the approach provides useful tools for establishing an appropriate degree of treatment and regulatory confidence in the performance data to support decision making. This training and guidance is intended to be beneficial to anyone involved with CERCLA, RCRA, brownfields, UST or any other regulatory program where S/S has been selected or implemented as a remedial technology.

For reference during the training class, participants should have available a copy of the process diagram, Figure 4-1 on page 31 of the ITRC Technology and Regulatory Guidance Document Development of Performance Specifications for Solidification/Stabilization (S/S-1, 2011) and available as a 1-page PDF at http://www.cluin.org/conf/itrc/ss/ITRC-SS-Process.pdf

ITRC (Interstate Technology and Regulatory Council) www.itrcweb.org
Training Co-Sponsored by: US EPA Technology Innovation and Field Services Division (TIFSD) (www.clu-in.org)
ITRC Training Program: training@itrcweb.org; Phone: 402-201-2419



Although I'm sure that some of you are familiar with these rules from previous CLU-IN events, let's run through them quickly for our new participants.

We have started the seminar with all phone lines muted to prevent background noise. Please keep your phone lines muted during the seminar to minimize disruption and background noise. During the question and answer break, press *6 to unmute your lines to ask a question (note: *6 to mute again). Also, please do NOT put this call on hold as this may bring unwanted background music over the lines and interrupt the seminar.

You should note that throughout the seminar, we will ask for your feedback. You do not need to wait for Q&A breaks to ask questions or provide comments using the ? icon. To submit comments/questions and report technical problems, please use the ? icon at the top of your screen. You can move forward/backward in the slides by using the single arrow buttons (left moves back 1 slide, right moves advances 1 slide). The double arrowed buttons will take you to 1st and last slides respectively. You may also advance to any slide using the numbered links that appear on the left side of your screen. The button with a house icon will take you back to main seminar page which displays our presentation overview, instructor bios, links to the slides and additional resources. Lastly, the button with a computer disc can be used to download and save today's presentation slides.

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ITRC (www.itrcweb.org) – Shaping the Future of Regulatory Acceptance

- Host organization
- Network
  - State regulators
    - All 50 states, PR, DC
  - Federal partners

    DOE DOD EPA

  - ITRC Industry Affiliates Program

    IAP

  - Academia
  - Community stakeholders
- Wide variety of topics
  - Technologies
  - Approaches
  - Contaminants
  - Sites
- Products
  - Technical and regulatory guidance documents
  - Internet-based and classroom training

The Interstate Technology and Regulatory Council (ITRC) is a state-led coalition of regulators, industry experts, citizen stakeholders, academia and federal partners that work to achieve regulatory acceptance of environmental technologies and innovative approaches. ITRC consists of all 50 states (and Puerto Rico and the District of Columbia) that work to break down barriers and reduce compliance costs, making it easier to use new technologies and helping states maximize resources. ITRC brings together a diverse mix of environmental experts and stakeholders from both the public and private sectors to broaden and deepen technical knowledge and advance the regulatory acceptance of environmental technologies. Together, we're building the environmental community's ability to expedite quality decision making while protecting human health and the environment. With our network of organizations and individuals throughout the environmental community, ITRC is a unique catalyst for dialogue between regulators and the regulated community.

For a state to be a member of ITRC their environmental agency must designate a State Point of Contact. To find out who your State POC is check out the "contacts" section at www.itrcweb.org. Also, click on "membership" to learn how you can become a member of an ITRC Technical Team.

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ITRC Course Topics Planned for 2012 – More information at www.itrcweb.org

Popular courses from 2011

- Bioavailability Considerations for Contaminated Sediment Sites
- Biofuels: Release Prevention, Environmental Behavior, and Remediation
- Decision Framework for Applying Attenuation Processes to Metals and Radionuclides
- Development of Performance Specifications for Solidification/Stabilization
- LNAPL 1: An Improved Understanding of LNAPL Behavior in the Subsurface
- LNAPL 2: LNAPL Characterization and Recoverability - Improved Analysis
- LNAPL 3: Evaluating LNAPL Remedial Technologies for Achieving Project Goals
- Mine Waste Treatment Technology Selection
- Phytotechnologies
- Permeable Reactive Barrier (PRB): Technology Update
- Project Risk Management for Site Remediation
- Use and Measurement of Mass Flux and Mass Discharge
- Use of Risk Assessment in Management of Contaminated Sites

New in 2012

- Green & Sustainable Remediation
- Incremental Sampling Methodology
- Integrated DNAPL Site Strategy

2-Day Classroom Training:

- Light Nonaqueous-Phase Liquids (LNAPLs): Science, Management, and Technology

October 16-17, 2012 in Novi, Michigan (Detroit Area)

More details and schedules are available from www.itrcweb.org.

Meet the ITRC Instructors

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Wilmer Reyes is an Environmental Engineer with the Delaware Department of Natural Resources and Environmental Control (DNREC). Since 2000, Wilmer has worked at DNREC as a project manager performing investigation and cleanup activities at state and federal superfund sites, including Brownfields. He initiated and developed the operation and maintenance program for remediated sites for the State of Delaware and he is part of the DNREC's Technical Advisory Group for remediation technologies. Prior to DNREC, Wilmer worked for 3 years as an environmental engineer for the Environmental Division of Southern Peru Copper Corporation, an American copper mining group based in Peru where he worked on environmental remediation and spill control projects associated with mining activities. Before that, he worked for 7 years in the environmental consulting field performing environmental impact assessments for mining and oil companies in Peru. Since 2009, Wilmer has contributed to ITRC as the Team Leader for the Solidification/Stabilization Team. Wilmer earned a bachelor's degree in forestry engineering from National Agrarian University, Lima, Peru in 1988 and a master's in environmental engineering from Las Palmas of Gran Canaria University in Spain in 1998.

Andy Garrabrants is an Associate Research Professor of Civil and Environmental Engineering at Vanderbilt University in Nashville, TN. He has developed leaching protocols, interpreted methodologies, and assessed models, primarily for inorganic constituents in hazardous, radioactive, and mixed waste systems. His research focuses on continuing development and acceptance of standardized approaches toward environmental impact assessment of solid wastes and construction materials and reuse of the byproducts of energy production and industrial processes. Other research interests include (i) release assessment approaches for semi-volatile organics in soil/cement mixtures (e.g., in-situ stabilized soils), (ii), physiochemical models for estimating source terms for risk assessment and risk evaluation, and (iii) leaching chemistry and long-term durability of cement-based solidification/stabilization (S/S) waste treatment and cementitious engineered barriers for nuclear waste disposition. He is actively involved with ASTM International D-34 Committee on Waste Management subcommittees for Treatment, Recovery and Reuse and Waste Leaching Techniques and in the ITRC Solidification/Stabilization team. Andy earned a Bachelor of Science (1994), a Master of Science (1998) and Doctor of Philosophy (2001) in Chemical and Biochemical Engineering at Rutgers, the State University of New Jersey in New Brunswick, New Jersey.

Rajesh (Raj) Singh works at Kleinfelder in Exton, PA as a senior remediation engineer responsible for technical oversight on remediation projects throughout the firm. Raj works closely with technical staff and project managers to ensure that projects are conducted on time, within budget, and with the highest level of technical quality. His expertise includes feasibility study, treatability study, engineering design, drawings, specifications and construction management of remedial systems for groundwater, soils and sediments. He has significant experience and knowledge in the complexities associated with implementation of Solidification/Stabilization (S/S) technology in the field. He has been a Program Manager for a $35 million closure/remediation of three NPDES permitted impoundments using cement-based in-situ S/S. The impoundment sediments were impacted by petroleum hydrocarbons, tar, PCBs and metals (arsenic, hexavalent chromium, total chromium, lead, antimony and other metals). As part of the S/S closure project, he directed waste characterization, treatability testing, process scale-up, engineering plans and specifications, bidding assistance, and contractor bid evaluation. He also managed the construction oversight and obtained no further action approval from the NJDEP for three impoundments. In addition to this work with ITRC S/S Team, Raj is a frequent speaker and presenter on S/S technology at professional conferences. Raj earned a bachelor's degree in Civil Engineering from Allahabad University, India in 1983 and a master's degree in Environmental Engineering from Rutgers University, New Brunswick, New Jersey in 1986.

Thomas Plante is a Senior Remediation Engineer with Haley & Aldrich located in Portland, Maine. As a consulting engineer, he has worked on remediation of contaminated sites for over 20 years, and has performed treatability evaluations, design, permitting, peer review, and construction management of in-situ solidification projects since 2000. He has worked for a number of utility clients and the Electric Power Research Institute (EPRI) investigating and remediating coal tar impacts from former manufactured gas plants and has prepared several technical research reports for EPRI on solidification/stabilization of coal tar sites, coal tar mobility, and containment barriers, among other topics. His solidification experience ranges from solidification of flyash ponds, to non-aqueous phase liquid containment, to mixed waste sites involving organics and inorganics, to complex solidification projects involving source and groundwater remedies, hydraulic and geochemical models and the use of additives for organic compound attenuation. Thomas routinely presents at technical conferences on solidification topics and has been an active member of the ITRC Solidification/Stabilization Team since 2009. Thomas earned a bachelor's degree in civil engineering from the University of New Hampshire in Durham, New Hampshire in 1987, and a master's degree in environmental engineering from the University of Massachusetts in Amherst, Massachusetts in 1990. Thomas is licensed as a Professional Engineer in Maine, New Hampshire, and Rhode Island.

Jim Harrington is currently the Director of Remedial Bureau A in the Division of Environmental Remediation at the New York State Department of Environmental Conservation In that capacity, he is responsible for 3 Sections that manage the remediation of contaminated sites in New York State's remedial programs on Long Island and the Eastern Adirondack region. He is also responsible for 2 Sections that are responsible for DEC's radiation program. Prior to the current position, he was Chief of the Technology Section which provides statewide technical support to the remedial programs relative to the application of innovative technology, soil cleanup objectives and regulatory interpretation. He has been involved in the review and approval of the use of a number of treatment technologies, including stabilization. He has been with the agency for over 30 years. Jim has been a member of ITRC since its inception in 1995 and has led and co-led a number of technical teams, been a member of the Board of Directors and has served as NY's Point of Contact since the founding of ITRC. He has a Bachelor of Science Degree in Civil and Environmental Engineering from Clarkson College of Technology (Potsdam NY 1978) and an Associate in Science Degree in Engineering Science from Morrisville Agricultural and Technical College (Morrisville NY 1976). He is a registered Professional Engineer in New York State (1983).

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Solidification/Stabilization (S/S) Guidance - Presentation Outline

- Technical Introduction
- Sections 1 & 2 – S/S Technology Overview
- Section 3 – Performance of S/S Treated Materials
- Section 4 – Performance Specifications in the S/S Design and Implementation Process
  - Q & A Break
- Section 5 – Treatability Studies
- Section 6 – Implementation
- Section 7 – Long-Term Stewardship and Case Study
  - Wrap Up
  - Q & A

No associated notes.

8

Solidification/Stabilization (S/S)

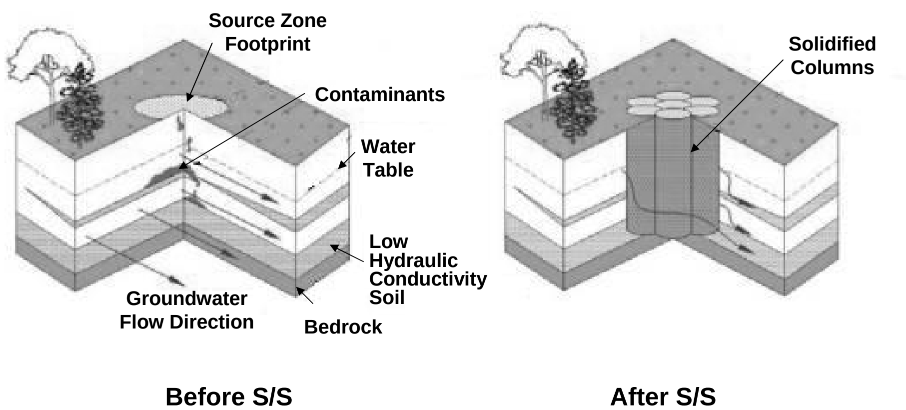
- Solidification
  - Entrap contaminants within a solid matrix
  - Coating of contaminant molecule
  - Organics are generally immobilized due to reduced hydraulic conductivity
- Stabilization
  - Bind or complex contaminants
  - May involve chemical transformation
  - Metallic contaminants are stabilized by precipitation or by interaction (e.g. sorption) with cement matrix
- Example: Lead

$$Pb(HCO_3)_2 + CaSO_4.2H_2O \rightarrow PbSO_4 + CaCO_3 + 3H_2O + CO_2$$

More information on an introduction to S/S and references for additional information are available in ITRC S/S-1: Sections 1 & 2

9

S/S Technology Process



The S/S process forms a granular or monolithic solid that incorporates the waste material.

A solid matrix, calcium-silicate-hydrate (C-S-H) is formed in presence of water.

The onsite application of S/S technology, as discussed in this training and the document, leaves treated material in place. Therefore, long-term stewardship is often required and will be discussed later in this training.

10

S/S Transformation of Waste Material

Oily Soil Before S/S

S/S Treated Soil

S/S Treatment

- ↑ Strength
- ↓ Hydraulic Conductivity
- ↓ Leachability

No associated notes.

11

Site Examples

Auger-mixed in situ S/S treatment of a former manufactured gas plant (MGP) site with coal tar contaminants at Kendall Square, Cambridge, MA, United States.

Excavator bucket mixing of contaminated sediment of a former steel mill operation, Sydney Tar Ponds, Sydney, NS, Canada.

The S/S process typically involves either the addition of reagents to water (to form a grout or paste) or the addition of dry reagents. The addition of dry reagents is more common. The S/S process then involves mixing the grout or paste with the contaminated material, using mechanical mixing equipment. The selection of the type of mixing equipment and methods is influenced by contaminant characteristics and site conditions such as:

•the depth and geometry of the impacted media;

•the presence of subsurface debris or very dense soil;

•the presence of buildings, railways, utilities, and other structures;

•and the proximity of surface water bodies.

Appendix A of the document provides more information on S/S equipment.

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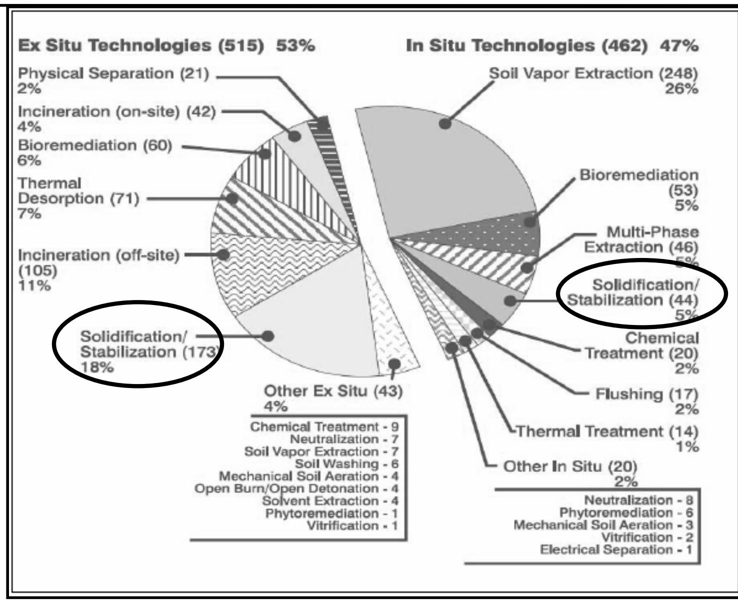
S/S Used Frequently at CERCLA Sites



EPA, 2009

According to the EPA 2009 Annual Status Report (EPA. 2009a *Technology Performance Review: Selecting and Using Solidification/ Stabilization Treatment for Site Remediation*. EPA/600/R-09/148. Office of Research and Development), S/S has been selected as a source control remedy at more than 200 sites (period 1982 to 2005), representing about 23% of remedies selected at CERCLA Superfund remediation projects.

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S/S Technology Advantages

- Effective in treating many contaminants
- Applicable for in situ or ex situ treatment
- Treatment period relatively short
- Can improve structural property of soil
- Can be applied in dry or wet conditions
- May be more cost-effective than off-site disposal

Former manufactured gas plant (MGP) site in Cambridge, Massachusetts

Section 2.4 of the ITRC S/S document.

In considering use of S/S technology, a sound understanding of site conditions is important as well as an understanding of the practical outcomes and limitations of the technology.

This list presents general non site-specific advantages of S/S technology. As with use of any technology, site specific conditions determine the potential feasibility and effectiveness of S/S, and therefore also determine the applicability of the advantages provided in the table.

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S/S Technology Challenges

- Contaminants are not destroyed or removed
- Uncertainties associated with prediction of long-term performance
- Potential changes in physical settings
- Volume increases in the treated mass may require management
- Options for treatment or post-treatment modifications limited
- Requires removal of debris or underground obstructions prior to treatment

Excavation of S/S column

Section 2.4 of the ITRC S/S document.

Technology should not be used if S/S is not suitable for the site, as determined after site characterization is complete. In addition, after conducting treatability studies, if S/S is not technically or economically feasible, other technologies may need to be evaluated.

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Applicability to Organics Contaminants

ITRC S/S-1: Table 2-1. Documented Effectiveness of S/S Treatment Chemical Groups

Contaminants	EPA 1993/2009	Other Refs
Halogenated VOCs, Non-Halogenated VOCs (i.e. solvents, aromatics)	No documented effectiveness	Pre-treat volatiles
HSVOCs, N-HSVOCs (i.e. chlorinated benzenes, PAHs)	Documented effectiveness	Pre-treat volatiles
PCBs, Pesticides	Documented effectiveness (in 2009 document)	
Dioxins/Furans	Potential effectiveness	Demonstrated effectiveness
Organic Cyanides, Organic Corrosives	Potential effectiveness*	Demonstrated effectiveness
Pentachlorophenol, Creosotes, Coal Tar, Heavy Oils	Not evaluated	Demonstrated effectiveness

* effectiveness not evaluated in EPA for 2009, therefore assumed to be same as 1993 evaluation

Table 2-1 in ITRC S/S document. It should be noted that effectiveness must be evaluated on a site-by-site basis; this table provides examples of contaminants that have been evaluated in general.

S/S technology has been used to treat both inorganic and organic contaminants. Early literature concerning effectiveness of S/S on organic hazardous constituents noted the possibility of the interference by organics with the setting of cement-based mixtures and as a result, a majority of S/S remedies were used for source control of inorganic contaminants (such as CERLCA sites). Current published case studies and other literature indicates that S/S technology can be effective or potentially effective for a wide range of contaminants as shown in this table and in Table 2-1 of the document.

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Applicability to Inorganic Contaminants

ITRC S/S-1: Table 2-1. Documented Effectiveness of S/S Treatment Chemical Groups

Contaminants	EPA 1993/2009	Other Refs
Volatile and Non-Volatile Metals	Documented effectiveness	
Asbestos	Documented effectiveness*	
Radioactive Materials	Documented effectiveness*	
Inorganic Corrosives, Inorganic Cyanides, Mercury	Documented effectiveness*	
Oxidizers, Reducers	Documented effectiveness*	

* effectiveness not evaluated in EPA for 2009, therefore assumed to be same as 1993 evaluation

Table 2-1 in ITRC S/S document. It should be noted that effectiveness must be evaluated on a site-by-site basis; this table provides examples of contaminants that have been evaluated in general.

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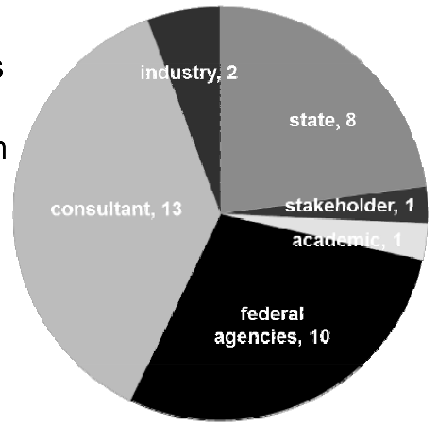
ITRC S/S Guidance Addresses Technical and Regulatory Barriers

- Inconsistent criteria for development of performance specifications
- Uncertainties associated with prediction of long-term performance
- Lack of methodologies for measure of long-term compliance
- ITRC S/S Team members collective experience addressed barriers in guidance



ITRC S/S Team members collective experience addressed barriers in guidance

No associated notes.

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What is Included in the ITRC Guidance and Training

- Performance specifications
  - Concepts
  - Identification and selection
  - Assessment methodology
- Technology performance
  - Treatability studies
  - Implementation
- Long-term stewardship
  - Considerations
  - Criteria for compliance


Technical/Regulatory Guidance

Development of Performance Specifications for Solidification/Stabilization

July 2011

Prepared by
The Interstate Technology & Regulatory Council
Solidification/Stabilization Team

ITRC Development of Performance Specifications for Solidification / Stabilization (S/S-1, July 2011)

Key points addressed by the guidance document and training to eliminate the barriers to technology usage are as follows:

•approach to identify and evaluate appropriate performance specifications, tests, and parameters.

•appropriate implementation and post-implementation sampling and testing.

•long-term stewardship to measure and verify long-term performance.

The document and training does *not* cover the following:

• S/S technology selection considerations; this document assumes that the technology has already been selected for further evaluation.

•sufficient details on the technology to support detailed design and implementation of S/S as a remedy or detailed review of work plans for design and implementation of S/S.

•regulatory requirements for materials taken off site or relocated on site after treatment, which may involve additional considerations such as Resource Conservation and Recovery Act (RCRA) waste generation or Land Disposal Restrictions (LDR).

•Recommendation of performance specification values or cleanup criteria applicable to S/S remediation projects.

Training Benefits by User Group

- Regulators
  - Identify and select appropriate performance specifications for design, implementation and monitoring of S/S remedies
  - Anticipate stakeholders potential concerns
- Consultants
  - Regulatory acceptance when using a consistent approach for developing performance specifications
- Owners and stakeholders
  - Better understanding of the benefits and limitations of the technology

No associated notes.

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Presentation Outline

- Technical Introduction
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- Wrap Up
- Q & A

Status update of progress through the training session.

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How do "Performance Specifications" differ from "Performance Goals"?

- Performance Specifications
  - Sets of Parameters + Tests + Criteria
  - Describe performance of S/S treated material
    - Bench scale - *Material Performance Specifications*
    - Field scale - *Construction Performance Specifications*
  - Applications to S/S mix design, treatment effectiveness, product consistency, modeling
- Material performance goals
  - Pre-established material targets based on site remediation goals
  - Describe how S/S fits into overall remedial approach

For the remainder of the training, the basic terminology presented here provides definitions for material performance goals and performance specifications. This terminology is addressed in detail in Section 3 of the document.

Material Performance Goals are design targets, established prior to development of a S/S remedy, that describe how a treated material will meet specific site remediation goals. These design targets form the basis for performance specifications for the design and implementation process and are used to formulate the list of characteristics for treatability testing, as presented in later slides.

Performance Specifications are a sets of parameters, tests and criteria that establish acceptable performance for S/S which will result in a material to meet material performance goals. Performance specifications may be developed to describe treated material performance in order to (i) serve as targets for the development of S/S mix designs during bench-scale testing (see Section 5 of the document) or (ii) to establish a baseline for consistency/compliance testing between field implemented materials and lab formulated mix designs (see Section 6 of the document). Performance specifications are referred to as Material Performance Specifications during bench testing and Construction Performance Specifications during implementation.

As an example of a performance specification for leaching, S/S remediation of the Peak Oil site focused on the following performance specifications

Performance Parameter: lead leachability

Performance Test: SPLP Method 1312

Performance Criteria: average of <282 ug/L with no values >500 ug/L

Performance specifications can be used as the building blocks for the formulation of S/S materials (Material Performance Specifications), demonstration of treatment effectiveness through comparison of untreated material performance to S/S treated material performance, consistency testing during implementation (Construction Performance Specifications), and as a source term for contaminant release that can be used in Fate and Transport Modeling.

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Retention of Contaminants in S/S Materials

- S/S remedy does not remove contaminants
- Chemically and physically retained in material with improved characteristics
  - Inorganic Contaminants
    - Stabilized by alkalinity
    - Adsorbed to mineral surfaces
    - Incorporated into mineral structure
  - Organic Contaminants
    - Partitioned with solid organic phases
    - Adsorbed to mineral surfaces
    - Absorbed by certain additives

One perceived disadvantage of S/S technology may be that contaminants in S/S materials remain "in place" after remediation. While it is true that contaminants are not removed during treatment, contaminants are retained by both chemical and physical means within a low hydraulic conductivity material with improved leaching characteristics over that of the untreated material. Both organic and inorganic contaminants may be retained within an S/S material; however, the mechanisms of retention may be slightly different.

Inorganic contaminants may be (i) stabilized to less soluble species by the alkalinity of the treated material [e.g., soluble Pb^{+2} will precipitate at pH 9 to solid $Pb(OH)_2$], (ii) absorbed to metal-hydroxide or other mineral surfaces, or (iii) incorporated into mineral structures during curing [e.g.,]. Many of these processes are pH-dependent.

Organic contaminants are primarily associated with solid organic phases (e.g., tars and grease) and slowly partition into pore water from these solid phases while to a lesser degree adsorbed to mineral surfaces. During S/S treatment, additives may to included in the mix design to specifically absorb certain organic contaminants. As the formulation cures, the additives are encapsulated within the matrix, effectively binding the organic contaminants.

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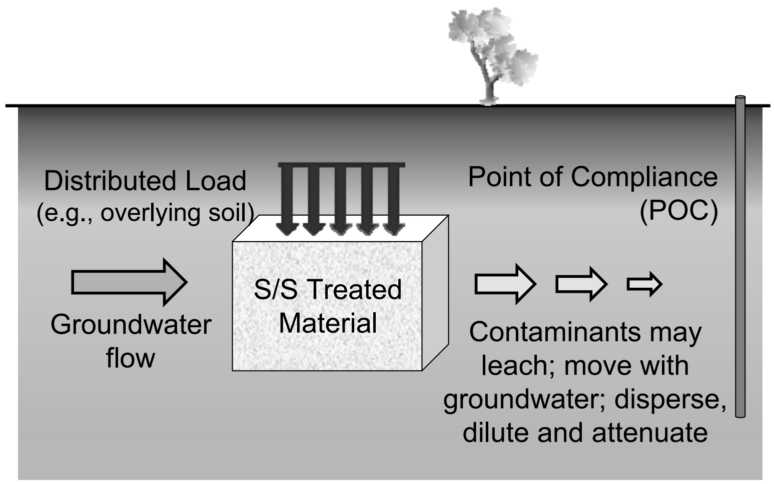
S/S Materials in the Environment



In a subsurface environment, an S/S material is subject to several inputs and outputs. The S/S material must be strong enough to resist a distributed load caused by the mass of overlying soil, operational equipment and surface structures. For applications below the water table, there is typically a horizontal flow of groundwater which contacts the S/S material. Contaminants retained within the S/S material may leach into groundwater where contaminants will travel with groundwater flow to some point of compliance (POC) such as a down-gradient well or a subsurface or surface water body. Along the way, contaminant concentrations will decrease due to dispersion, dilution and attenuation such that leaching concentration or flux limits set at the S/S material may be 1-2 orders of magnitude higher than groundwater concentrations at the POC.

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Three Key Performance Parameters

- Strength
  - Withstand overlying loads
- Hydraulic Conductivity
  - Manage water exposure
- Leachability
  - Retain contaminants

Based on the interactions with the environment presented in the previous slide, three key performance parameters were identified:

Strength

Hydraulic Conductivity

Leachability

These key parameters represent the primary parameters which can typically be used to define the important performance characteristics for an S/S material. Not all of these parameters may be pertinent for every site and additional parameters may be identified based on individual site goals and conditions.

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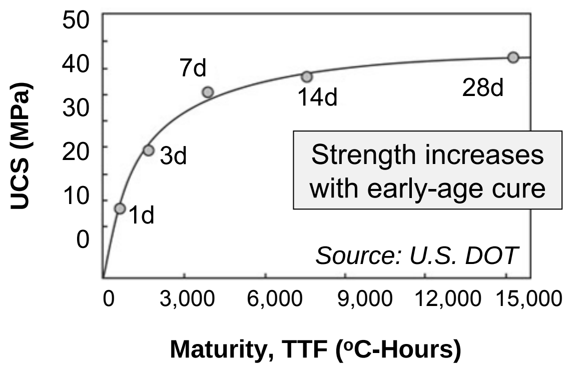
Strength: Ability to Withstand Loads

- Unconfined Compressive Strength (UCS)
  - Most commonly-used parameter for S/S
    - Indicator of *chemical reaction* or binding
    - Indirect indication of *durability*



ASTM D1633:
UCS for soil-cement cylinders

The *Strength* of a material is its ability to withstand an applied physical stress without incurring an inelastic strain (damage) leading to structural failure.

As an S/S performance parameter, strength is typically monitored to ensure that the S/S-treated material has at least as much bearing strength as surrounding material. Minimum compressive strength criteria are set such that S/S material will support the loads imposed by the equipment used in implementation; however, high strength values may be required depending on other considerations.

A secondary purpose for testing strength during the S/S treatment process is as an indirect indicator of durability. As a rule of thumb, materials with higher initial compressive strength are typically considered to be more resistant to aging. Thus, strength may be used as an indicator while selecting appropriate S/S treatment additives to maximize durability as well as a monitor of performance during S/S application.

Several measurements of strength (e.g. flexural, tensile, compressive strength) may be important; however, unconfined compressive strength (UCS), or the capacity of a material to withstand axially-directed pushing forces, is the most commonly utilized strength measurement for S/S materials.

For most S/S materials which form a monolithic mass, ASTM D1633 is a typical and appropriate UCS test method specific to molded soil-cement cylinders. The method provides two alternative procedures based on specimen size and component particle size. When S/S treatment results in an encapsulated granular material, ASTM D2166 may be used to provide an approximate measure of the compressive strength in a cohesive molded sample in terms of total stresses. UCS is expressed as the load per unit area in units of pounds per square inch (psi) or kilo-newton per square meter (kN/m^2) at failure (ASTM D1633) or at 15% axial strain (ASTM D1633).

The figure on this slide shows that UCS typically increases with early-age curing. Thus, it is difficult to compare the UCS results for materials cured for different lengths of time. Test specimens should be prepared and cured for a similar length of time prior to testing when UCS is used as a measure of product consistency. Figure source: Maturity Testing of Concrete Pavement Applications", Federal Highway Administration, U.S. Department of Transportation, http://www.fhwa.dot.gov/pavement/pccp/pubs/06004/index.cfm.

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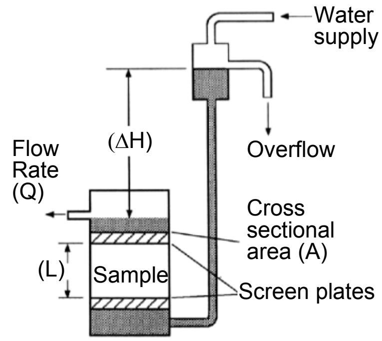
Hydraulic Conductivity: Water Movement Through a Porous Material

- Hydraulic conductivity (K)
  - K relates groundwater flow (Q) to hydraulic head ($\Delta H/L$)
- Relative hydraulic conductivity
  - Difference in K between adjacent materials
  - Determines
    - water contact mode
    - primary leaching mechanism

D'Arcy's Law

$$Q = A \cdot K\left(\frac{\Delta H}{L}\right)$$



ASTM D5084:

Hydraulic Conductivity is a measureable material property related to ease of movement of water through a porous medium under groundwater flow conditions governed by Darcy's Law. This term is often used interchangeably with the more general term, *permeability*, which relates to the ease with which a fluid (e.g., water, oil, air, etc.) will pass through a porous medium. Although these terms are similar, a significant difference exists in that permeability depends on the properties of both the material and the penetrating fluid whereas hydraulic conductivity depends only on the properties of the material structure.

Since hydraulic conductivity is more easily measured independent of fluid properties, it is a more appropriate performance parameter for S/S materials than permeability.

Depending on the soil type, the hydraulic conductivity of surrounding materials may range from approximately 10^{-2} cm/s for sandy soils to 10^{-7} cm/s for clay soils. Most S/S materials have very low hydraulic conductivity and, in many cases, values similar to clay (e.g., on the order of 10^{-7} cm/s) are desirable in order to reduce the potential for contaminant migration.

Perhaps more important that the absolute material value of hydraulic conductivity is the relative hydraulic conductivity between the S/S material and the surrounding soil. The relative hydraulic conductivity determines if groundwater is diverted around the outside of the S/S mass or if groundwater will percolate through the S/S mass. In turn, the basic mechanisms for leaching and contaminant release rely on this water contact mode.

ASTM D5084 is a common testing procedure for hydraulic conductivity of saturated soils and soil-cement materials. The method contains procedures for a falling head permeameter and a constant head permeameter (shown in the schematic on this slide).

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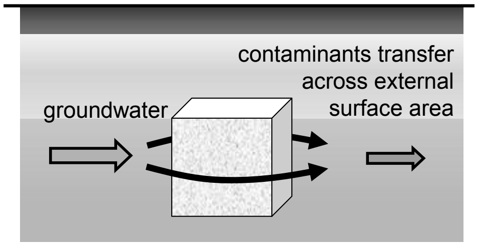
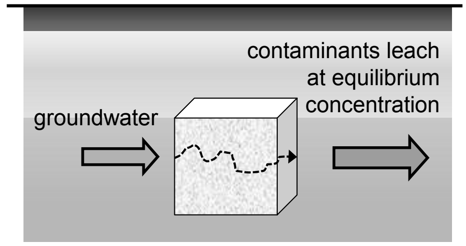
Why is Relative Hydraulic Conductivity Important?

$K_{S/S} << K_{soil}$



- Water is diverted around material
- Exposed surface area limited to external surface
- Contaminant release rate controlled by *Rate of Mass Transfer*

$K_{S/S} \sim K_{soil}$



- Water percolates through material
- Continuous pore area exposed
- Release concentrations based on *Liquid-Solid Partitioning* (local equilibrium)

Contaminant release under equilibrium conditions will always be greater than under mass transfer conditions.

As an illustration of the importance of relative hydraulic conductivity, consider two scenarios.

In the first scenario, the hydraulic conductivity of the S/S material is much less than that of the surrounding soil, such that groundwater flow is diverted around the outside of the S/S material. In this case, only the external surface area of the S/S material is exposed to groundwater and contaminants must travel through the S/S pore structure to the surface before they are released into the passing groundwater. This is often called a *mass transport-controlled* or *diffusion-controlled* release scenario.

In the second scenario, there is not significant difference in hydraulic conductivity value between the S/S material and the surrounding soils, such that groundwater is free to percolate through the treated material. Thus, the entire pore space of the S/S material is exposed to groundwater flow and the partitioning of contaminants between the solid S/S material and its liquid pore space (i.e., liquid-solid partitioning or local equilibrium) will dictate the concentrations associated with contaminant release. This is sometimes referred to as an *equilibrium-controlled* release scenario.

Fortunately, the second scenario is not common in well-designed S/S technologies as leachate concentrations in equilibrium-controlled scenarios will always be greater than leachate concentrations in mass transfer-controlled release scenarios. This is one reason why it is often desirable to know the hydraulic conductivity of subsurface soils around the contamination zone and to design an S/S formulation that provides are reasonably significant relative hydraulic conductivity.

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Leachability: Potential to Release Contaminants

- Leachability
  - Extent of Leaching - mass release (mg/kg solid)
  - Rate of Leaching - mass transport or flux (mg/m^2 s)
- Leaching
  - Process of solid material constituents moving into a contacting liquid phase
  - Principle pathway for inorganic and non-volatile organic contaminants
  - Based on results of one or more leaching tests
    - Promulgated Leaching Protocols (e.g., TCLP, SPLP)
    - Consensus Standards (ASTM, American Nuclear Society)
    - Emerging EPA Leaching Methods (LEAF)

Leaching is the process where constituents of a solid material, typically considered to be contaminants but may also be species that may be elements of the mineral structure, are released into a contacting liquid phase. *Leachability* refers to the extent or rate of leaching. Since leaching is the principle pathway for release of inorganic and non-volatile organic contaminants in the subsurface environment, *leachability* is considered a key performance parameter.

The basic principles of leaching are best described using the analogy of making of coffee or tea. In both situations, a mass of solid (ground coffee bean or tea leaves) is contacting with a liquid (water).

•During percolation of coffee, water is passed through a bed of coffee grounds which flushes the pore solution through the bed into the pot below. The concentration of coffee in the pore solution is determined by the local equilibrium between the pore water and the coffee grounds. The leachability is this case is based on the concentration of coffee in the pot of water and can be determined on the basis of the mass of coffee released per mass of coffee grounds place in to the percolator.

•When brewing tea, the mode of water contact is essentially flow around a tea bag. The constituents in the tea bag are released into the pore solution of the bag and must move by diffusion into the bulk liquid external to the tea bag. The flux of tea across the interface between the bag and the water determines the concentration of tea in solution and the leachability of tea is dependent on the time to steep the tea bag. Leachability, in this case, is based on the release of tea per steeping time.

For environmental purposes, leachability (whether determined by the extent or rate of leaching) is often based on the results of one or more leaching tests. Caution should be used when selecting an appropriate leaching method as some of the most commonly-used leaching tests are designed for specific purposes which may or may not represent the leachability measurement that is applicable for S/S materials. It is important to note that there are emerging leaching test approaches that are more robust and generally applicable to a wide range of applications.

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Leaching Environmental Assessment Framework (LEAF)

- LEAF consists of:
  - Four leaching test methods
  - Data management tools
  - Assessment approaches
- Provides a material-specific “source term” for release
  - Demonstration of treatment effectiveness
  - Release estimation
  - Fate and transport modeling
- Leaching tests define characteristic leaching over a broad range of release-controlling factors

Recently, the U.S. EPA Office of Resource Conservation and Recovery has proposed the adoption of a robust “characterization-based” leaching assessment approach for applications where current regulatory tests (e.g., TCLP and SPLP) are not required or best-suited. The EPA has selected the four leaching methods of the Leaching Environmental Assessment Framework (LEAF) for review and inclusion into its compendium of laboratory methods, SW-846.

LEAF consists of a suite of four leaching methods, data management tools (e.g., data recording, archiving and visualization), and leaching assessment approaches that provide a material-specific release “source term”. The release from this source term may be useful for S/S material assessment in several applications including demonstrating that S/S treatment has been effective in mitigating contaminant release, estimating the potential release rates and extents at S/S material-groundwater interface, and as a source for release into groundwater for down-gradient fate and transport modeling.

Rather than simulate any particular leaching scenario, the LEAF leaching tests characterize leaching behavior of a solid material over a range of conditions controlled by a select set of leaching factors.

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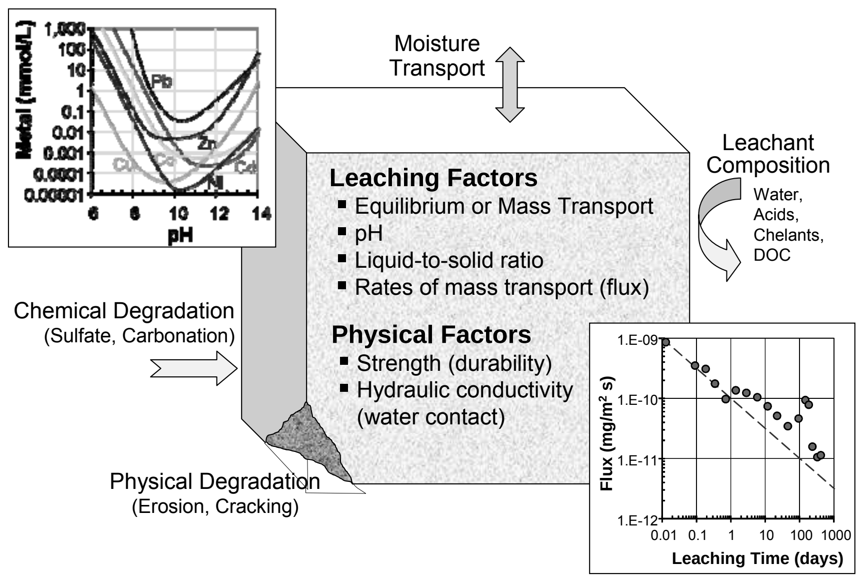
Factors Influencing S/S Material Leaching Performance



The figure in this slide is a simplified version of Figure 3-1 in the document. The figure shows an S/S material and the leaching and physical factors that influence material performance. In terms of leaching performance, the figure identifies three primary factors – pH, liquid-to-solid ratio, and rates of mass transport as being significant. These three are the primary focuses of the LEAF leaching methods.

Many of the factors shown in this figure (e.g., strength, hydraulic conductivity, pH, mass transport rates) can and should be accounted for by the mix design during S/S treatment development. Changes in these factors, and hence changes in leaching, are likely to develop over time; however, normal fluctuations in material properties or external stresses are not likely to result in catastrophic failure of the S/S treatment. For example, physical degradation through cracking is often of great concern for regulators. However, cracking is a naturally occurring phenomena for any cement-based material, including commercial structural cements and concretes, and may be seen as a factor with minor impact. All S/S materials have some degree of cracking as a consequence of the curing process. These cracks tend to be disconnected micro-cracks which do not significantly affect the key performance parameters identified in the ITRC guidance. Even in the case where advanced cracking results in a “through crack” transecting a monolithic material, overall performance is maintained as two monoliths instead of one. Complete physical degradation of the S/S material through due to erosion and cracking may take centuries to develop to any significant degree.

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LEAF Test Methods

PreMethod 1313 – Liquid-Solid Partitioning as a Function of Eluate pH using a Parallel Batch Procedure

PreMethod 1314 – Liquid-Solid Partitioning as a Function of Liquid-Solid Ratio (L/S) using an Up-flow Percolation Column Procedure

PreMethod 1315 – Mass Transfer Rates in Monolithic and Compacted Granular Materials using a Semi-dynamic Tank Leaching Procedure

PreMethod 1316 – Liquid-Solid Partitioning as a Function of Liquid-Solid Ratio using a Parallel Batch Procedure

Notes: "PreMethod" designates these methods as preliminary versions of EPA methods under review for publication in SW-846.

Based on the figure in the previous slide, the four LEAF leaching tests directly address the major factors that control leaching performance as shown in red text. The remaining leaching factor, that of equilibrium vs. mass transport based release scenarios is the focus of each of the methods as shown in underlined text.

The LEAF methods are currently (as of August 2011) considered to be "preliminary versions of EPA Methods" as designated by the "PreMethod" notation. Adoption of these methods and inclusion on the SW-846 as "Draft Methods" is anticipated to occur within the 2011 calendar year. The method titles and numbers are subject to change during the review process.

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Where Are Leaching Tests Useful?

- Mix Design
  - Selection of reagents
  - Comparative assessment of candidate recipes
  - "Baseline" for comparison to field materials
- Compliance
  - Demonstration of treatment effectiveness
- Consistency
  - Field materials compared to bench-scale baseline
- Release Prediction and Modeling
  - Source term for fate and transport modeling
  - Support for establishing monitoring schedules

The LEAF test methods and leaching assessments in general may be useful at several stages in the process of development, implementation and monitoring of S/S treatments. Comparing the results of leaching tests between candidate S/S mix designs can inform the selection process and full characterization (e.g., equilibrium- and mass transport-based testing) at the bench-scale can set a "baseline" for comparison to field implemented materials later in the process. Leaching assessments can be used to demonstrate the effectiveness of treatment in comparison to release of untreated materials. During implementation, leaching results from field collected samples may be used to assess consistency of the S/S product from between columns or treatment areas. In addition, the same tests can be used to ensure that the performance of field-applied materials is consistent with the "baseline" performance demonstrated for lab formulated mix designs during treatability studies. A properly design and characterized leaching assessment approach provides the source term for contaminant release that is useful for groundwater fate and transport modeling or for establishing a schedule for periodic monitoring in support of long-term stewardship.

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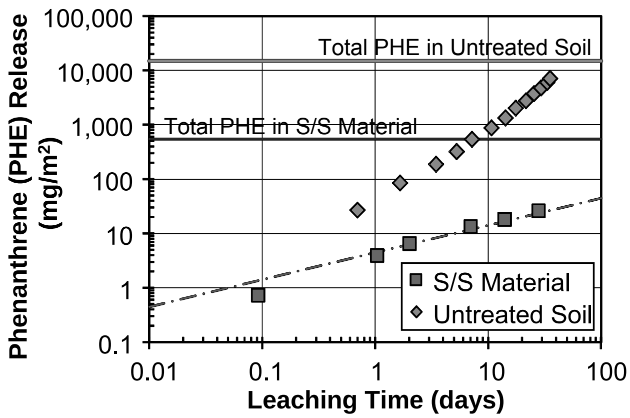
Cumulative Release from Treated and Untreated MGP* Soil



S/S Material

- Data from PreMethod 1315 (modified for organic species)

Untreated Soil

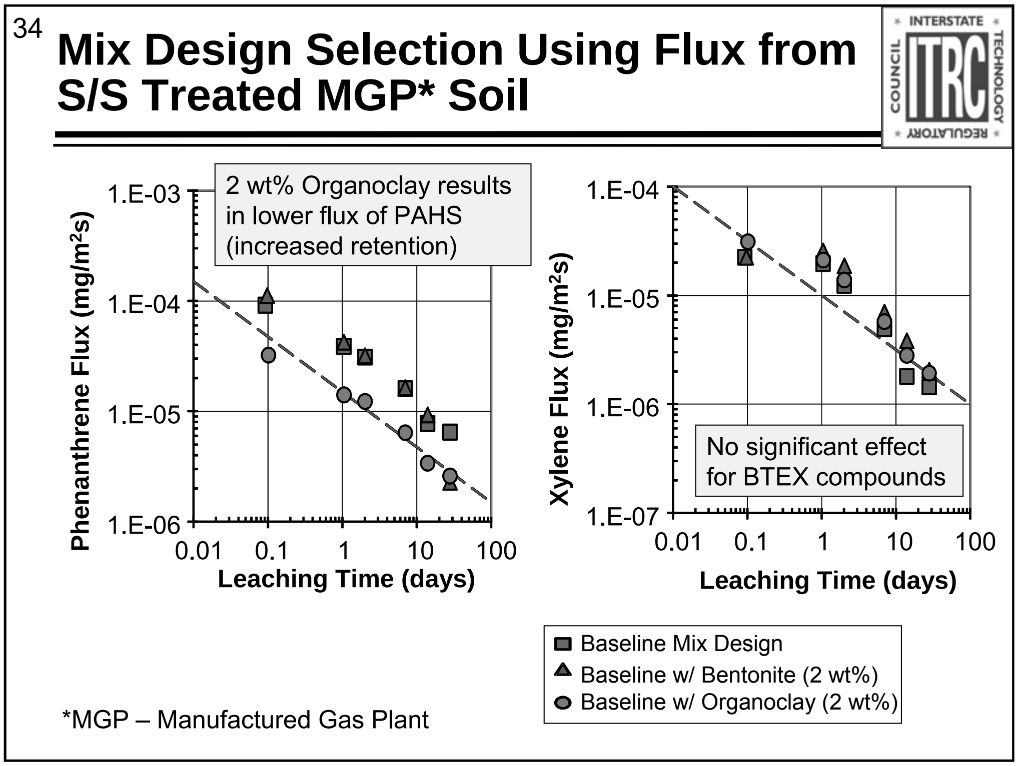
- Data from PreMethod 1314 (percolation column)
- Site-specific information relating L/S percolation rate

S/S treatment significantly decreases both the total content and the rate of PHE release

*MGP – Manufactured Gas Plant

The data in this figure shows an example application of LEAF leaching methods to demonstrate that S/S treatment has a positive impact on the release of phenanthrene (PHE), a common polycyclic aromatic hydrocarbon (PAH), at a former manufactured gas plant (MGP) site. The graph show phenanthrene release in mg/m2 of external material surface area for a 1 m3 volume of untreated soil (shown as brown diamonds) and S/S treated material (shown as red squares). Also show on the graph are the total content of PHE in both materials. The figure shows more than two orders of magnitude greater release for untreated materials after 30 days of leaching than in the S/S materials.

Testing of the S/S material was conducted by PreMethod 1315 modified to address the low aqueous solubility of PAHs and the volatility of VOCs. For the untreated material, percolation test data from PreMethod 1314 providing release as a function of liquid-to-solid ratio was adapted to a time basis by relating the groundwater flow rate to the volume of water passing through the untreated material as a function of time.



Leaching tests are also very useful in support of S/S mix design development at the bench-scale. The two graphs on this slide show the flux (release per surface area per time) of phenanthrene on the left and xylene on the right from three different S/S formulations of a coal tar impacted MGP soil. The mix designs shown here include a “baseline” design (red squares) and the baseline with either 2 wt% bentonite clay (green triangles) or organoclay (blue circles) added.

The flux of phenanthrene is significantly decreased by the addition of 2 wt% organoclay, but addition of bentonite does not seem to impact the leaching performance over that of the baseline formulation. In the right hand graph, there is no significant effect of clay addition (neither bentontite nor organoclay) on the flux of xylene. Based on these results alone, the S/S formulation with 2 wt% addition of organoclay would be the best choice for a mix design due to the increase in leaching performance for PAHs. However, leaching performance is only one factor in the selection of an appropriate S/S formulation for treatment of a site and addition factors may sway the final decision.

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Example Performance Tests
(ITRC S/S-1, Table 3-3)

Performance Parameter	Performance Measurement	Example Performance Test(s)
Strength	UCS	ASTM D1633
Hydraulic Conductivity	Hydraulic Conductivity	ASTM D5084
Leachability		
Treatability Study	Local Equilibrium	PreMethod 1313 PreMethod 1314 PreMethod 1316
Treatability Study	Mass Transfer (flux)	PreMethod 1315 PreMethod 1315 (modified) ANSI 16.1
Consistency Testing	various	PreMethod 1316 SPLP abbreviated mass transfer tests

Several test methods may be useful during the process of design and implementation of S/S technology. Recommended performance parameters, the performance measurement to apply to each performance parameter, and suggestions for appropriate performance tests to provide the performance measurement are shown in the table (Table 3-3 in the document). With respect to leachability, the proper selection of an appropriate test method is somewhat unique due to the complexity of the leaching process. Test methods for strength and hydraulic conductivity tend to be of short duration and require little to no interpretation of the results and these tests may be conducted on S/S material samples after short cure times and compared directly to performance criteria as long as it is recognized that these performance parameters will continue to develop as the S/S material ages.

Compliance Testing

Compliance testing is utilized to evaluate cured material properties for direct comparison to project performance criteria. The types of compliance tests can vary on a project-specific basis based on the remedial objectives; however, the most common compliance tests are strength (UCS via ASTM D1633) and hydraulic conductivity (ASTM D5084). In addition, a leachability test may be incorporated into the construction performance criteria, although the usefulness of the results in support of time-sensitive decisions is somewhat suspect due to time required to cure field samples and perform these tests as discussed in Section 3. Specifications for collection and curing of field samples should be identified in the project specification so that samples collected in the field are tested under the same conditions as bench-scale samples (e.g., cure times typically range between 7 and 28 days). For UCS testing, it is common practice to prepare several replicate specimens and begin testing at 7 days to have an early indication if the strength criteria will be met. Test methods, test conditions, specimen geometry, sample specimen preparation methods, and curing conditions should be consistent between the bench, pilot, and full-scale implementation phases to reduce test results variability to the extent practical. While test results will have some inherent variability due to material heterogeneities, it is important to minimize induced variability due to specimen or test condition variability.

Consistency Testing

Consistency testing consists of real-time or short-term evaluations of treated material during implementation used to adjust reagent addition rates or mixing procedures in order to maintain material properties consistent with construction performance specifications. Performance measurements are compared to construction performance specifications to determine if the material properties are consistent with those properties measured during the bench and pilot phases. Consistency test measurement should not be considered for determining compliance with material performance goals since performance tests used to establish compliance with performance parameters (e.g., compressive strength, hydraulic conductivity, and leachability) typically are performed on well-cured specimens (e.g., > 28 days curing) over testing duration ranging from days to week. The time lag between material production and compliance verification can be long relative to the production schedule and might result in removal or retreatment of large volumes of non-compliant treated material. Thus, compliance is established during bench scale testing while implementation decisions rely on consistency testing in comparison to previously established construction performance criteria

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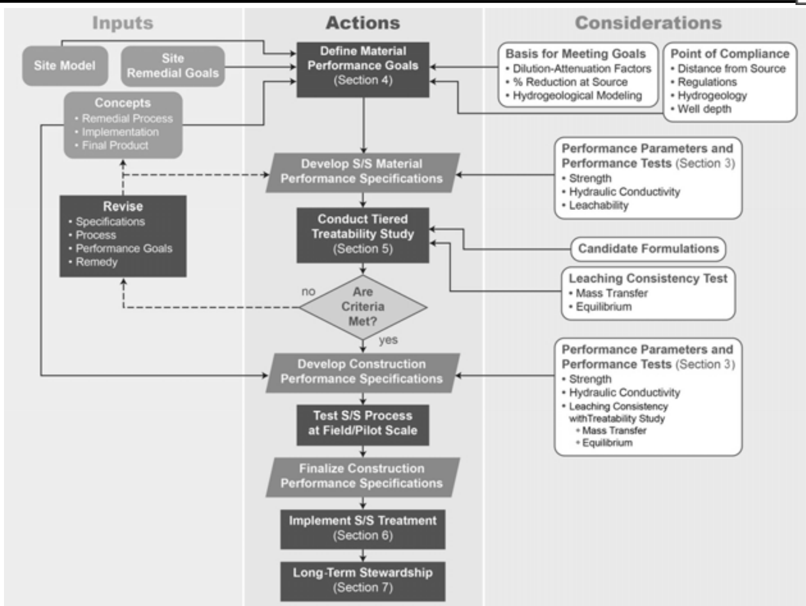
S/S Process Flow Chart
(ITRC S/S-1, Figure 4-1)



This is the S/S Process Flow Chart that will be used throughout the remainder of the training as a guide. It is recommended that participants have a copy of the flow chart handy in order to follow along with the presentation.

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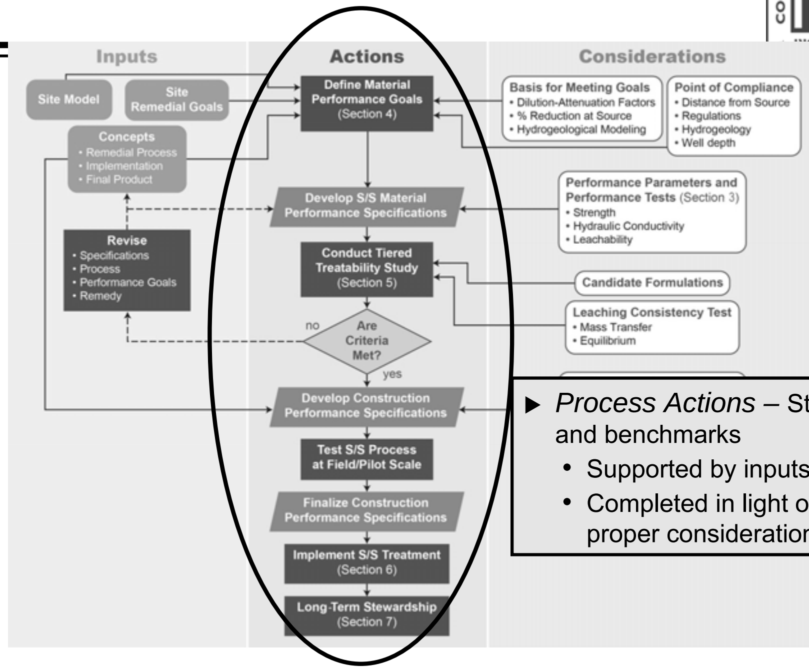
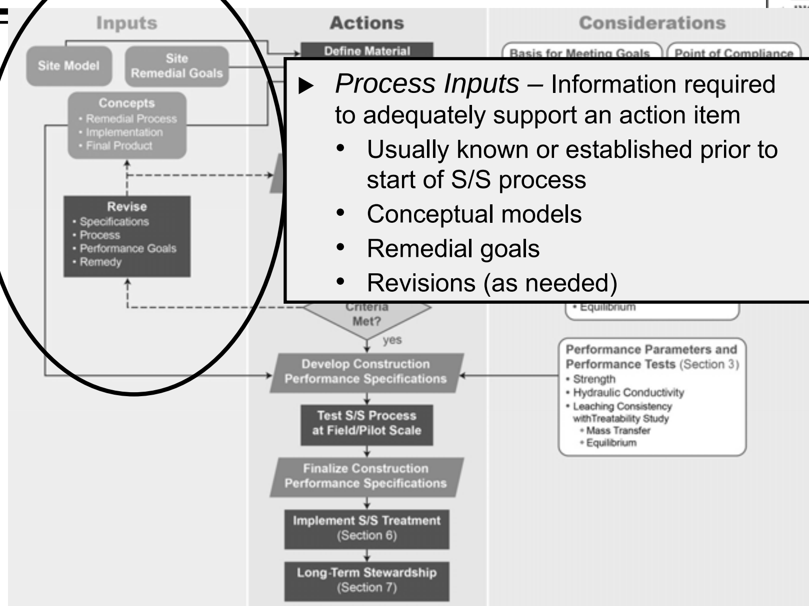
S/S Process Flow Chart



- *Process Actions* – Steps and benchmarks
  - Supported by inputs
  - Completed in light of proper considerations

The S/S Process Flow Chart is comprised of three color-coded columns of information. The center column with the blue background represents the Actions taken through the process. This is the main path through the S/S Design and Implementation Process from the decision to use S/S as a treatment remedy through to the long-term stewardship of a completed S/S treatment project. The Actions of the process consist of steps or benchmarks of the process. Actions are supported by Inputs shown in the left-hand column and Considerations in the right-hand column.

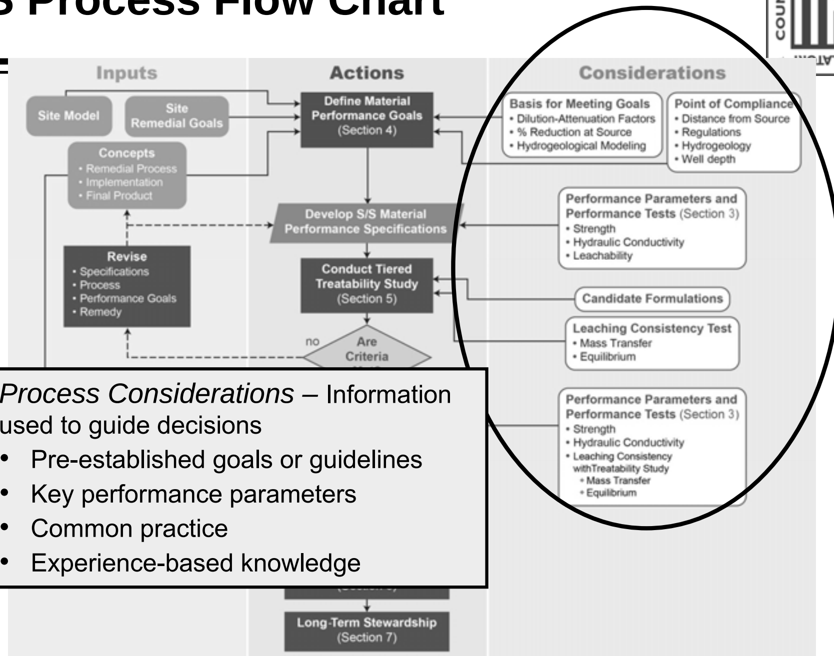
S/S Process Flow Chart



- *Process Inputs* – Information required to adequately support an action item
  - Usually known or established prior to start of S/S process
  - Conceptual models
  - Remedial goals
  - Revisions (as needed)

The inputs to the S/S Design and Implementation Process include all known information about the site as well as conceptual models and goals for the treatment process and site remediation as a whole. Conceptual models (e.g., the equipment and process for implementing S/S technology) and goals for the site remediation should be know "up front" in order to shape the decisions of the S/S material design. However, these conceptual models and goals should not be viewed as rigid to the point that they cannot be revised during the S/S Design and Implementation Process in order to have the treatment be effective.

S/S Process Flow Chart



- *Process Considerations* – Information used to guide decisions
  - Pre-established goals or guidelines
  - Key performance parameters
  - Common practice
  - Experience-based knowledge

The considerations for the S/S Process include all the “bounding information” that helps to shape the decisions made in the Actions column. This information can include pre-established goals or guidelines, the key performance parameters as applied to the site, common practice and techniques acquired through experience with remediation and S/S technologies.

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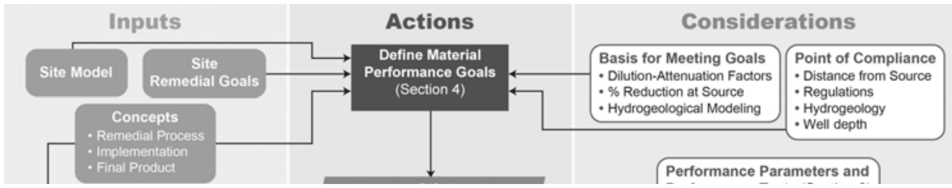
Material Performance Goals



- Action – Define Material Performance Goals
  - Material Performance Goals – How is the treated material expected to meet site remediation goals?
- Inputs
  - Site Model – What are current site conditions?
  - Remedial Goals – What will remediation accomplish?
  - Process/Product Concepts – How will remediation be completed?
- Considerations
  - Basis for Meeting Goals – How will goals be assessed?
  - Point of Compliance – Where will goals be assessed?

As an example of how Inputs and Consideration affect Actions, let’s look at the first Action in the flow chart – Define Material Performance Goals. Material performance goals are design targets that describe a treated material that will meet specific site remediation goals. These design targets form the basis for performance specifications for the design and implementation process and are used to formulate the list of characteristics for treatability testing, as presented in later slides.

The goals that are used to determine how an S/S material should perform should be based on the information that is typically contained in a site model (e.g., groundwater flow, hydraulic conductivity, extents of contamination, etc), the role that S/S will play in the overall remedial goals for the site, and a general idea of how the S/S treatment will be implemented. The specific of the material performance goals will be shaped by the considerations of where and how the goals will be assessed (e.g., % reduction in leaching at the source, absolute groundwater concentrations at some well or water body).

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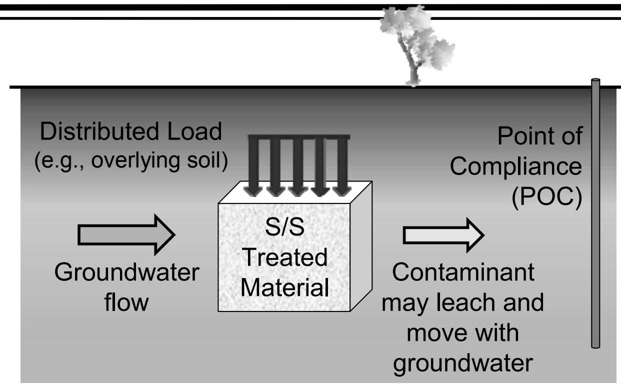
Materials Performance Goals



- Example Material Performance Goals
  - Support overlying subsurface, operational loads, future use loads
  - Provide for diversion of groundwater around the material
  - Address remedial goals for release/groundwater quality at a POC

Keeping in mind the inputs and outputs of S/S materials placed in the environment, an example set of material performance goals might include:

•The material should be strong enough to support the loads of the overlying soil, operational load (e.g., construction equipment, rigs, etc) and future use loads (e.g., buildings, structures).

•The material should have a low enough hydraulic conductivity to divert groundwater around the treated material such that mass transport will dominate the rate of contaminant release.

•The material should address all of the site remedial goals for water quality at the pre-established POC.

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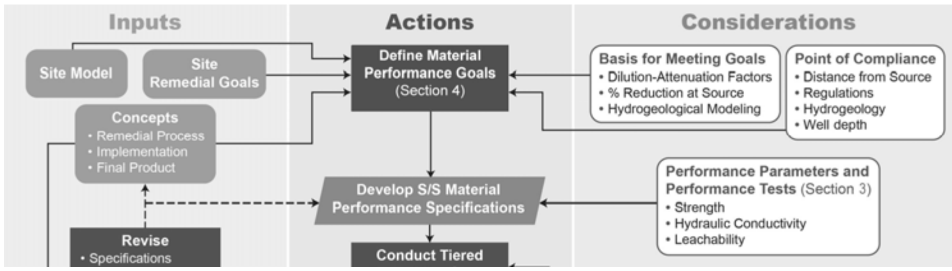
Material Performance Specifications



- *Action - Develop S/S Material Performance Specifications*
  - Used to define acceptable material for bench-scaled treatability

- Considerations
  - Key Performance Parameters
  - Performance Tests – Which are appropriate and applicable?
  - How to Establish Criteria – Absolute values? Averages? Allowance for out-of-spec values?

The second step in the S/S Design and Implementation Process is Development of S/S Material Performance Specifications. Whereas material performance goals provide the basis for how the S/S remediation as a whole should behave, Material Performance Specifications are set of Performance Parameters, Performance Tests, and Performance Criteria that describe the minimum performance of an acceptable S/S material formulation. These specification are a crucial component in the development of an appropriate S/S treatment. Material performance specifications are developed to guide the evaluation of whether the treated material will meet performance goals and site remediation goals.

Considerations that shape the development of S/S Material Performance Specifications include the available and applicable key performance parameters identified for the site. The ITRC guidance identified the following key performance parameters:

•Unconfined Compressive Strength (UCS)

•Hydraulic Conductivity

•Leachability

However, these key parameters may not be applicable or adequate to all sites and should be evaluated prior to completing this Action step.

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Things to Remember

- Performance specifications
  - Material Performance Specifications
  - Construction Performance Specifications
- Key performance parameters
  - Strength
  - Hydraulic Conductivity (relative to surrounding soil)
  - Leachability
- LEAF
- Example Performance Tests (ITRC S/S-1, Table 3-3)
- Flowchart of S/S Process (ITRC S/S-1, Figure 4-1)

Important points to remember for this segment of the training.

Question and Answer Break

- Technical Introduction
- Sections 1 & 2 – S/S Treatment Overview
- Section 3 – Performance of S/S Treated Materials
- Section 4 – Performance Specifications in the S/S Design and Implementation Process
- Q & A Break
- Section 5 – Treatability Studies
- Section 6 – Implementation
- Section 7 – Long-Term Stewardship and Case Study
- Wrap Up
- Q & A

No associated notes.

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- ▶ Wrap Up
- ▶ Q & A

No associated notes.

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Treatability Studies

- Purpose and objective of treatability studies
- Bench-scale testing
- Pilot tests/field demonstrations
- Scale-up considerations

During this section of the presentation you will hear:

1.Why treatability testing is important,

2.What are some of the important factors to be considered while performing treatability testing, and

3.Generally how treatability testing is performed.

Typically treatability studies can be performed both at bench-scale and pilot- scale level. Bench-scale testing is particularly important in S/S because most of the formulation and design development is based on results obtained during the bench-scale level. Pilot scale testing or some times referred as field demonstration, are performed typically on large and difficult sites. I will also present information on scale-up considerations.

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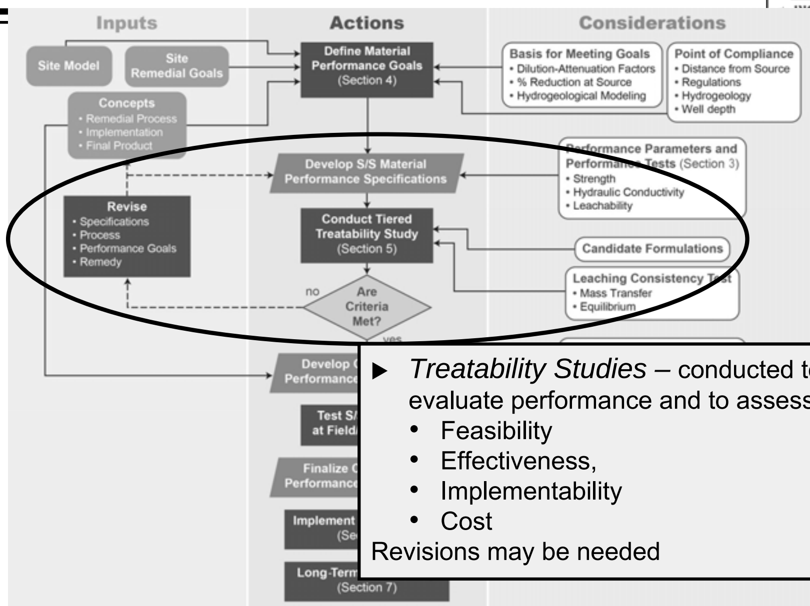
S/S Process Flow Chart



- *Treatability Studies* – conducted to evaluate performance and to assess:
  - Feasibility
  - Effectiveness,
  - Implementability
  - Cost

Revisions may be needed

No associated notes.

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Treatability Studies Objectives

- Develop S/S formulation to meet project objectives
- Determine impact of selected reagents on contaminants
- Optimize the reagents/admixtures dosages
- Assess contaminant emissions
- Finalize material handling criteria
- Determine physical and chemical uniformity of the material
- Determine the volume increase
- Finalize construction parameters and performance criteria

Treatability testing are typically conducted to assess the feasibility of the technology by evaluating the effectiveness, implementability, and cost. Some times a technology can be feasible at the bench-scale level, but may not be possible to implement in the field. In another case, the technology could be feasible, but cost prohibitive.

For most technologies including S/S, effectiveness, implementability, and cost are site-specific . Site-specific treatability studies in the laboratory and/or the field provide valuable information needed to evaluate the feasibility and establish the design of treatment remedy. In S/S treatability testing typically involves characterizing the untreated contaminated material and evaluating the technology performance under various operating conditions. Treatability testing provides valuable site-specific information to support selection and implementation of a remedial action. Therefore, treatability tests may be conducted for both technology feasibility prior to selection and to develop process design parameters for scale up for full–scale implementation. Additional information for conducting treatability testing is provided in published documents and guidance (EPA 1992, USACE 1995, Environment Agency 2004a, EPRI 2009).

The objectives of treatability testing, which should be clearly defined prior to testing. The objectives include the following:

- selection of correct reagent(s)
- determination of the impact of selected reagents on other contaminants
- optimization of the reagent(s) dosages
- identification of emission of contaminants
- identification of material handling issues
- assessment of the physical and chemical uniformity of the contaminated material
- determination of the volume increase due to addition of reagent(s)
- finalization of performance criteria

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Bench and Pilot-Scale Treatability Testing

- Bench-scale– provides important information
- Pilot-scale – confirms the full-scale approach
- Selection of candidate reagents requires knowledge of:
  - Process track record
  - Interference and chemical incompatibilities
  - Metals chemistry
  - Compatibility with disposal or re-use
  - Cost

Bench-scale testing is crucial in design of a S/S project. It provides valuable information for developing the full-scale design and includes:

Preparation of work plan

Sample collection

Sample characterization

Formulation preparation

Preliminary testing

Laboratory testing

Data analysis, assessment and validation

A typical treatability testing program is an iterative process which determines the optimal formulation and associated design parameters to meets the project objectives. At bench-scale level one can test several reagents and admixtures or combination of these reagents and admixtures without incurring huge cost. Normally during bench-scale testing you mix pre-selected candidate admixtures and reagents with the untreated material and test the samples with pocket penetrometer first to assess the strength.

Treatability testing for S/S may include both bench-scale and pilot testing, although full scale pilot testing may be considered during startup of field implementation. Once treatability testing is completed, a plan for treating the full extent of the contaminated material in the field is based on the results of the tests.

Potentially applicable admixtures and reagents should be identified prior to bench-scale testing. The identification of potentially applicable reagents depends on several factors:

•Contaminant(s) to be treated;

•Concentration of contaminant;

•Expected Performance Parameters;

•Geotechnical properties

Identification of potentially applicable reagents is typically based on practitioner's experience in implementing S/S. In the absence of experience, a literature survey is good starting point. However, literature survey may identify several potentially applicable reagents, which may result in high cost and long testing time.

Selection of candidate reagents requires that the practitioner know about:

•Process track record of the reagent in treating contaminant

•Interference and chemical incompatibilities

•Metals chemistry

•Compatibility with disposal or re-use

•Cost

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Sample Collection Critical and Requires Careful Planning

- Appropriate locations
- Sample compositing
- Method for collecting representative samples
- Full-scale implementation approach

Collecting representative samples to perform treatability testing – This is very important and critical task because the results obtained from the treatability testing will be used to develop the full-scale performance criteria. If representative samples are not collected during the treatability testing you may develop the formulation based on a sample that is not representing the field conditions.

Collecting representative sample requires:

•careful understanding of site,

•chemicals of concerns,

•contaminant distribution,

•heterogeneity,

•location,

•sample compositing,

•type of mixing will be employed, and

•how the full-scale implementation will be performed.

Sample characterization:

•Total waste analysis for target contaminants including those that may leach in S/S process

•Leaching tests on untreated material

•Other – pH, redox potential, oil & grease

•Baseline physical characteristics – specific gravity, bulk density, permeability, moisture content, particle size distribution, geo-tech properties, debris

•Heterogeneity of contaminant distribution

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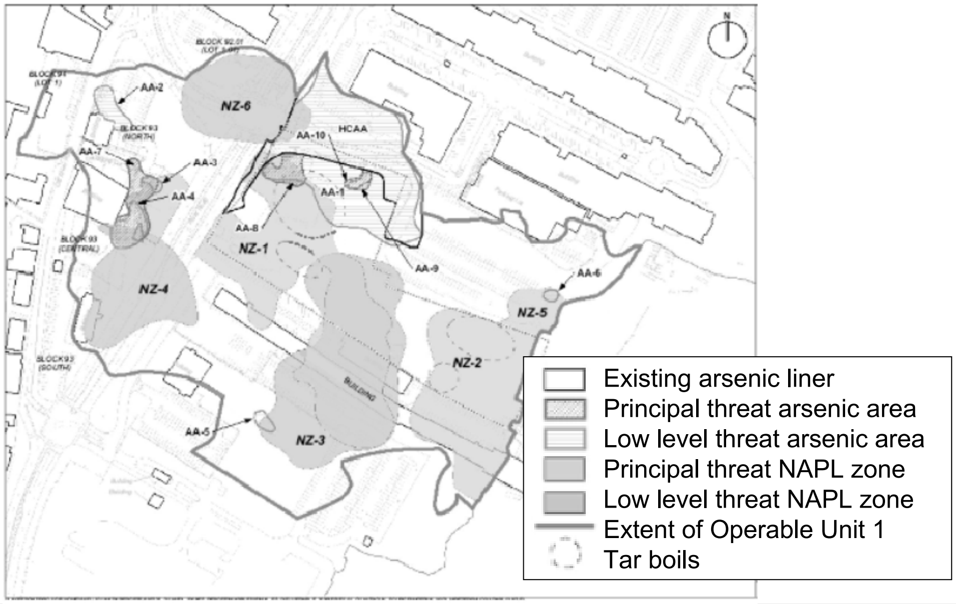
Sample Collection Example



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- careful understanding of site,
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- contaminant distribution,
- heterogeneity,
- location,
- sample compositing,
- type of mixing will be employed, and
- how the full-scale implementation will be performed.

Sample characterization:

- Total waste analysis for target contaminants including those that may leach in S/S process
- Leaching tests on untreated material
- Other – pH, redox potential, oil & grease
- Baseline physical characteristics – specific gravity, bulk density, permeability, m. content, particle size distribution, geo-tech properties, debris
- Heterogeneity of contaminant distribution

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Sample Characterization

- Total waste analysis for target contaminants including those that may leach in S/S process
- Leaching tests on untreated material
- Other – pH, redox potential, oil & grease
- Baseline physical characteristics – specific gravity, bulk density, permeability, m. content, particle size distribution, geo-tech properties, debris
- Heterogeneity of contaminant distribution

After sample collection, a baseline analysis should be performed on the samples collected for testing at the bench-scale level through a process of chemical and physical testing. Physical characterization test usually includes moisture content, grain size distribution, Atterberg limits and compaction. Chemical characterization may include total chemical analysis of the samples collected.

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Bench-Scale Testing Tiered Testing Approach

- Tier 1
  - Physical tests UCS, and Hydraulic Conductivity using candidate reagents, narrow the range of reagents.
- Tier 2
  - Testing the selected reagents and combination of reagents and additives (if used) to assess contaminant immobilization.
- Tier 3
  - Optimizing the reagents and additives to minimize the quantity required to meet the performance criteria.
- Tier 4
  - Scale-up considerations, development of QC parameters, baseline consistency tests, and performance criteria acceptance limits.

Bench-scale testing is usually performed in a laboratory where small amount of contaminated material is tested in a tiered approach. As indicated, the treatability testing is an iterative process and the results obtained from the previous step is evaluated for subsequent tests.

Selected reagents are mixed with the samples to evaluate the preliminary performance parameters (such as strength, hydraulic conductivity and leachability). Preliminary testing in the laboratory may include testing for strength by use of a pocket penetrometer over a period of time, visual observation, chemical testing, and/or geotechnical testing. The information obtained from performing laboratory tests will result in identification of reagents that can treat the contaminated material.

Once the treatability tests are completed, if the data meet the performance criteria, pilot test studies or field demonstrations may be considered prior to full scale implementation. If the performance criteria are not met, the specifications, process, or performance goals may need to be revised and the treatability study repeated (see flow chart). If the criteria cannot be met, the remedy selection may need to be revised. Validation of the lab data is a step that is always included before analyzing data results. Often, data validation is provided by the laboratory

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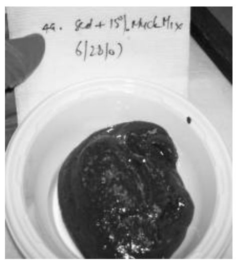
Laboratory Testing

Untreated Sample in the Field

Sample Collection



Sample Characterization

S/S Sediment Sample

No associated notes.

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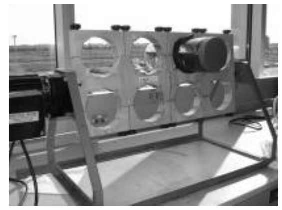
Laboratory Analysis – Treated Samples



- Chemical testing
  - Total chemical analysis
  - Leaching Test
  - Documenting pH of extract
- Other testing
  - Strength
  - Hydraulic conductivity

No associated notes.

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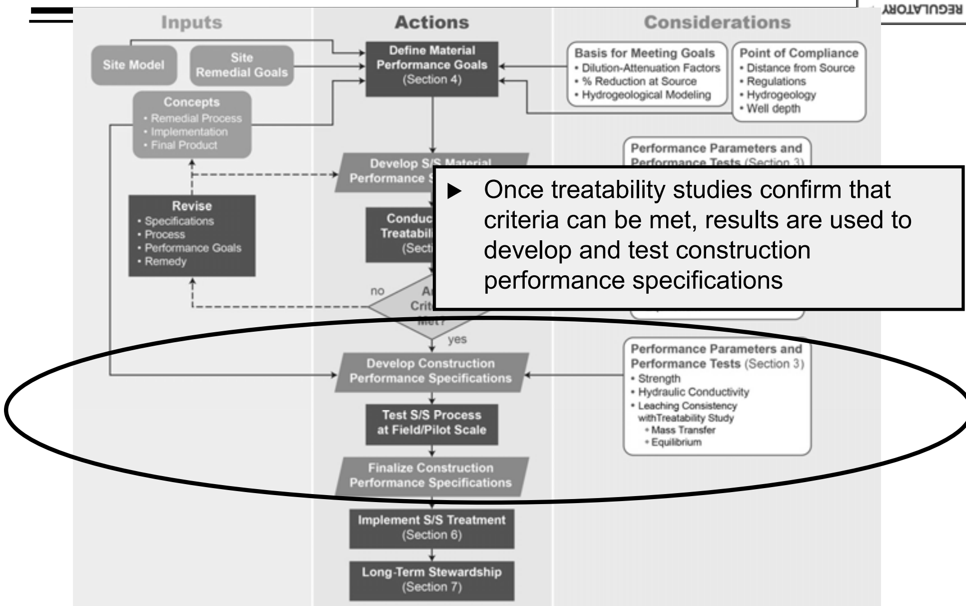
Treatability Testing Evaluation

Key Performance Parameter	Performance Measurement	Example Criteria
Strength	Unconfined Compressive Strength	344.7 kN/m2 (50 psi) to 689.4 kN/m2 (100 psi)
Hydraulic Conductivity	Hydraulic Conductivity	$5x10^{-6}$ to $1x10^{-6}$ cm/sec (relative K)
Leachability		
	Site conceptual model Remedial goals Risk-based limits % leaching reduction MCL or other goals Point of compliance	

These are examples of performance parameters and the numerical criteria used at some sites. These are not to construed as recommendation for S/S. Every site will need to develop its own performance criteria.

S/S Process Flow Chart



- Once treatability studies confirm that criteria can be met, results are used to develop and test construction performance specifications

No associated notes.

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Pilot Test Studies / Field Demonstrations

- Verifies the process variables selected as part bench-scale testing
- Further develops and optimizes the process and construction parameters for full-scale implementation

Preparing test samples in the field

Field curing specimens in a humid atmosphere (water bath).

Following selection of the design mixes obtained from bench-scale treatability testing, the next phase of the project may involve a pilot test in the field. The pilot scale is intended to verify the process variables selected as part of bench-scale testing and, if required, further develop and optimize the process and construction parameters for full-scale implementation.

Pilot tests should utilize the equipment planned for full scale implementation.

The pilot test scales-up the design mixes developed during bench-scale treatability testing for application under actual field conditions based on the ability to meet the performance criteria, implementability, and cost. Because pilot-scale testing is intended to simulate the physical as well as chemical parameters of a full-scale testing process, the treatment unit size and the volume of contaminated material to be processed in a pilot scale is much greater than for bench-scale testing.

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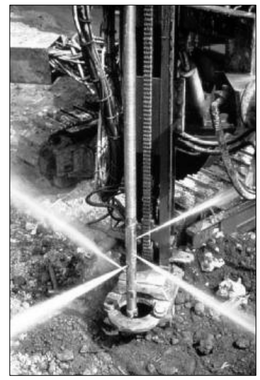
Scale Up Considerations

- Generally focused on the materials handling aspects of the S/S process

Auger mixing at a former MGP site.

Treatment by rotary blender at former wood-preserving site Port Newark, NJ



Jet grouting

Since the S/S chemistry is already established, the scale-up from bench-scale to full scale field implementation is generally focused on the materials handling aspects of the S/S process. Scale-up from bench-scale to full-scale field implementation should address the following:

•equipment selection and sizing (See Appendix A of document for more information on equipment)

•type of equipment and mixing time/energy departed for homogenization

•chemical reagents storage and delivery methods

•evaluation of treated material consistency tests and strength gain rates

•pretreatment of soil/sediment

•presence of debris

•presence of underground utilities

•mixing and curing time and methods employed

•method and measurement for delivering correct reagent quantity

•quality assurance

Scale-up considerations are the last step of the trial approach of the treatability test programs. After completion, the next step is to implement a verification process during S/S implementation

Treatability Tests Key Points

- Bench-scale testing is important for developing and optimizing the mix design/formulation
- Sampling for treatability testing is crucial
  - Worst-case and average case samples
- Testing should mimic the field implementation approach (depth, reagent form, sequence)
- Appropriate characterization test(s) to obtain data as input in the GW model (if needed)
- Key performance parameters
  - Strength
  - Relative hydraulic conductivity
  - Leachability

No associated notes.

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No associated notes.

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Implementation

- Performance verification during implementation
- Sampling and testing considerations
- Test data evaluation
- Long-term performance considerations

Section 6 of ITRC Guidance Document covers performance verification during implementation.

Section 2 of ITRC Guidance Document covers technology overview.

Appendix A of ITRC Guidance Document illustrates various S/S equipment and implementation methods.

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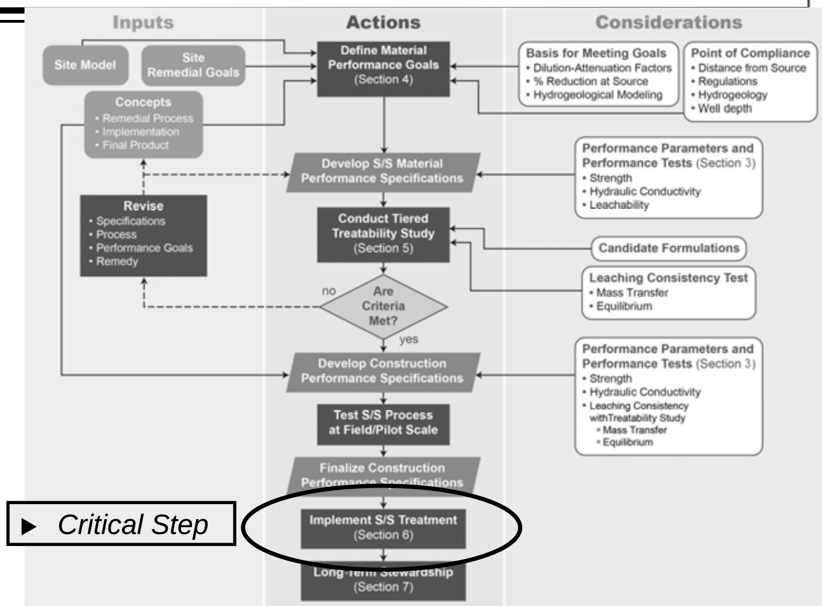
Performance Verification During Implementation



The overall success or failure of a S/S remedy depends upon successful implementation of the construction phase. The following key areas should be monitored and documented as necessary during the implementation phase to ensure that performance specifications have been achieved:

- consistent preparation of the designed reagent blend in the correct proportions in accordance with the mix formula determined through the bench- and pilot-testing
- sufficient mixing of the reagents with the contaminated materials in the correct proportions to create a treated material
- sampling of treated materials to verify compliance with S/S performance specifications
- verification of treatment of the entire volume of contaminated materials

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Sampling and Testing During Implementation

- Observations, sampling, testing
  - Demonstrate that the treated material achieves the project's performance specifications
  - Documents that the proper reagents were mixed in accordance with the approved mix design
  - Allows for adjustments to be made as needed to respond to variations in material and/or site conditions
  - Getting it right the first time

Field QA/QC program involves observations, sampling, and testing

- •Routine equipment calibration
- •Reagents verification
- •Mixing thoroughness and observation of changes in waste characteristics
- •Survey control of treated material mix cells or columns
- •Consistency testing of grout slurry and freshly mixed materials
- •Sampling and curing for laboratory testing
- •Tracking test data

When using cementitious reagents that cure to form a solidified soil or "monolithic" end product, getting it right the first time is critical, as remixing partially or fully cured material may be ineffective at homogenizing material.

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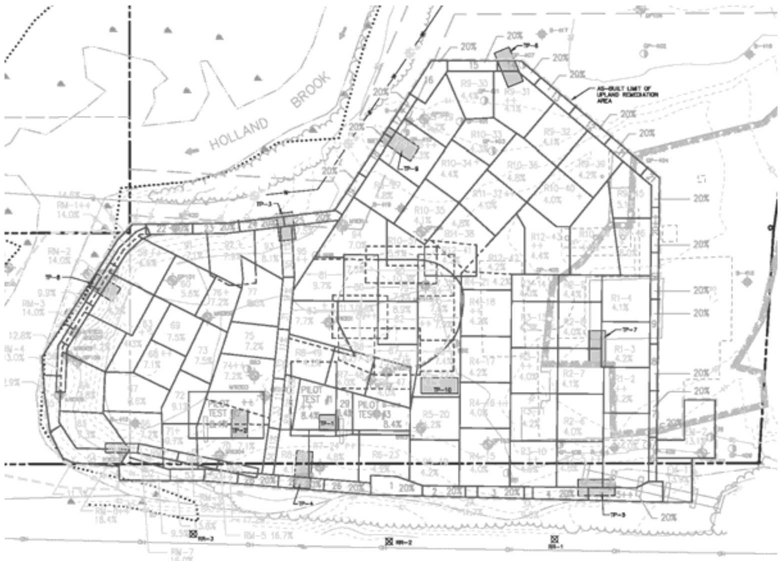
Documenting Mix Cells and Test Data



Accurate plan of mix cells or columns is necessary to document that all target material is treated.

Plan enables tracking of sampling and testing locations and test results. Enables identification of problem areas.

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Sampling of Treated Material for Testing




•A statistically valid sampling program should be developed to guide sampling and testing of treated materials.

•Various methods available to sample in-situ treated materials.

•Field sample preparation and curing must be consistent with methods used and/or developed in the bench-scale testing for comparability.

•Extra specimens useful for replicate testing or verifying unexpected results.

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Types of Performance Verification Testing

- Consistency testing
  - Real-time or short-term evaluation of treated material through observation and testing
  - Does treated material exhibit characteristics consistent with bench and pilot baseline observations?
- Compliance testing
  - Evaluate cured material properties using performance tests for direct comparison to project performance criteria

Consistency Testing:

Consistency testing is utilized during construction for real-time or short-term evaluation of treated material to determine if the material properties are consistent with those established during the bench and pilot phases that result in a material that meets the project performance criteria. Therefore, it is important that the test methods, test conditions, specimen geometry, sample specimen preparation methods, and curing conditions be consistent between the bench, pilot, and full-scale implementation phases to reduce test results variability to the extent practical. While test results will have some inherent variability due to product heterogeneities, it is important to minimize induced variability due to specimen or test condition variability.

Use of consistency tests allows for real-time or short term adjustment in reagent addition rates or mixing procedures to maintain material properties in a range where the risk of failing performance tests is low.

Compliance Testing

Compliance testing is utilized to evaluate cured material properties for direct comparison to project performance criteria. The types of compliance tests can vary on a project-specific basis based on the remedial objectives. The most common compliance tests for solidified materials are strength and hydraulic conductivity. Leachability compliance testing is used somewhat less often, and the need for compliance testing depends on the mechanism of treatment employed (i.e., solidification versus stabilization). When hydraulic conductivity reduction is the primary mechanism utilized for leaching reduction (i.e. solidification as opposed to chemical stabilization) and leaching performance has been adequately demonstrated in the treatability study phase, consistency tests can be used in lieu of leachability compliance tests during construction. Where stabilization reactions are the primary mechanism of treatment, leaching tests such as SPLP may be appropriate as compliance tests.

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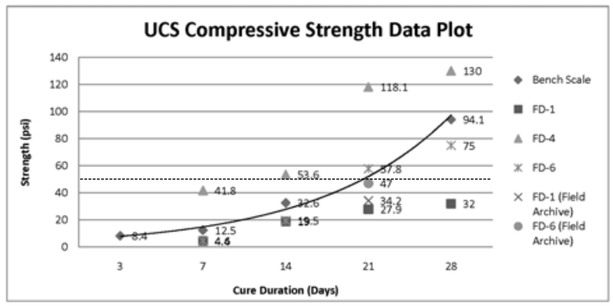
Consistency Test Examples

- Slump
- Short-term strength gain
- Visual observation
- Leaching consistency tests
  - SPLP – type
  - Monolith leach
- Other



Consistency test protocols are typically established in the bench and pilot phases for use during the construction phase. Consistency tests can be performed on freshly mixed material or cured specimens and a combination of both is recommended. Real-time testing of freshly mixed material is intended to identify significant variations in material properties that can affect performance test results and may include tests such as slump, material moisture content, grout density and viscosity, mixing thoroughness (mixed material homogeneity). Short term tests on specimens as curing progresses may include, but are not limited to:

•strength gain rate using a pocket penetrometer

•visual observation of bulk sample specimens cured in a 20-lt (5-gallon) bucket

•short term leaching tests, including SPLP test, an abbreviated monolith leaching test, or other leaching tests that may be deemed appropriate for a specific project. SPLP results, if SPLP tests are conducted, are used only to determine if the leaching of contaminants falls within the range established for this same test during the bench-scale testing and is not used as a performance criteria.

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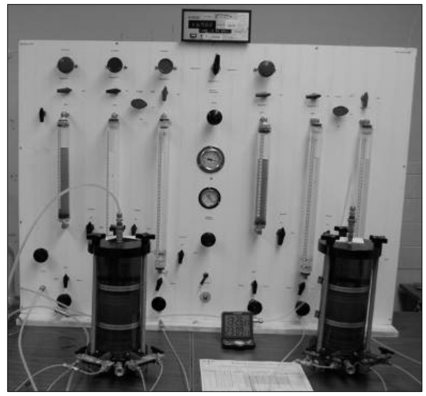
Compliance Tests Based on Design Performance Criteria

- Compliance tests may include:
  - Strength at specified cure time
  - Hydraulic conductivity at specified cure time
  - Leaching performance
  - Other chemical tests for stabilization reactions



No associated notes.

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Evaluating Field Performance Data

- Performance criteria statements
  - Require all results to pass **OR**
  - Accept some limited variability without compromising the overall success of the remedy (i.e., tolerance intervals)
  - Extra samples for testing is useful
- Consider remedial objectives and reality check
  - Bulk performance of the treated mass
  - Material to be treated **will** vary in both physical and chemical properties

Sampling and testing of treated S/S material should be performed to adequately assess representative samples from the entire area, volume, and depth of the S/S treatment area. The total number of samples collected and tested should enable statistical evaluation of test results if necessary.

Peak Oil Case Study example (Case Study #2, Appendix C)

S/S Specifications	**Avg**	**Allowance**
Strength (USC psi)	>50	None
Permeability (cm/sec)	$<1\times10^{-6}$	1×10^{-5}
Leaching Lead (ug/l)	<282	<500

Example statement with tolerance intervals:

> Strength: Average of all performance samples must not be less than 50 psi, no individual sample shall be less than 40 psi, and no more than 20% of the performance samples shall be less than 50 psi.

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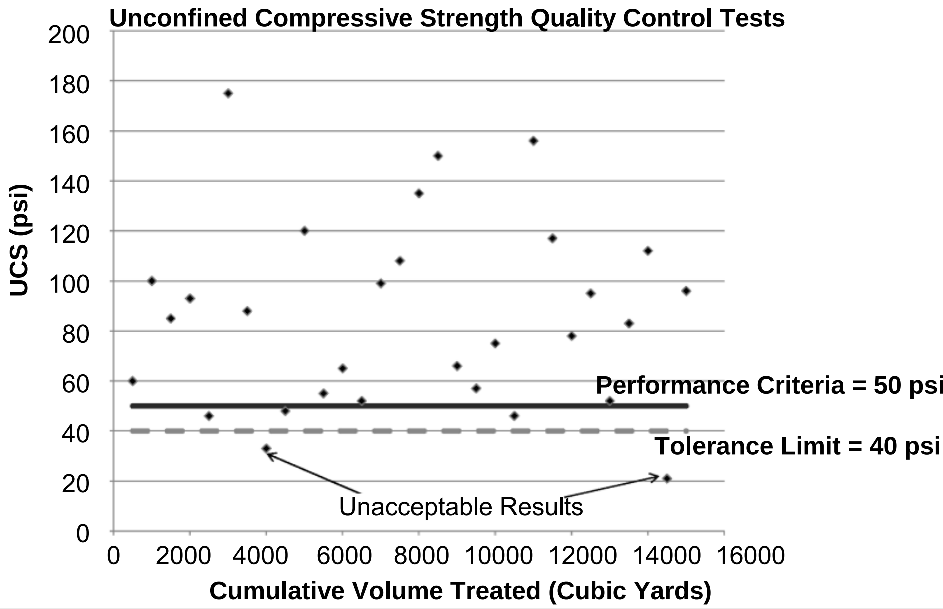
Sample Performance Data Tracking



Tracking consistency and compliance test data during construction is a critical function to enable identification of problem areas either with reagents, batch preparation or batch plant operation, waste characteristics, or construction means and methods. Many types of data tracking including individual test results, moving averages, control charts, tolerance intervals should be considered as part of the construction quality control and quality assurance program.

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Long-Term S/S Performance

- Properly designed S/S remedies can be expected to last on the order of decades to centuries. Success tied to remedial goals!
- Research studies have been conducted to evaluate the long-term performance of S/S remedies.
  - EPRI studies
  - PASSiFy project
  - Other literature
- EPA has used S/S effectively on many sites.

A number of studies and predictive modeling suggest that a properly designed S/S remedy which accounts for the contaminant properties and the disposal/management scenario conditions can be expected to last on the order of decades to centuries (Environment Agency 2004b, Perara et al. 2004, PASSiFy 2010).

Research on the structural integrity of S/S treated monoliths has led to several conclusions: the properties of the treated material typically do not change significantly; if the properties do change, those changes do not significantly affect remedy performance; and methods for sampling the monolith impact sample quality (such as through fracturing) and therefore alter the measured properties as recorded in the laboratory (PASSiFy 2010).

An EPRI-funded project conducted at a former MGP site 10 years after S/S implementation included geotechnical, chemical, leaching, and solid-phase geochemical analyses of samples taken from the site. Using the sampling data, contaminant transport modeling was used to predict the leaching potential at the site and concluded that the treated contaminated material still met the performance standards as designed. In addition, contaminant concentrations at the monitoring point of compliance were predicted to continue meeting performance criteria for at least 10,000 years. Short-term groundwater monitoring results supported this hypothesis (EPRI 2003).

In another study, a research consortium led by the University of Greenwich (United Kingdom), the University of New Hampshire, and INERTEC (France) conducted a research project entitled Performance Assessment of Solidified/Stabilized Waste-forms (PASSiFy). The objective of the PASSiFy Project was to assess the time-dependent performance of the S/S remedy at 10 sites where S/S was implemented between 1989 and 2006. The report concludes that all the sites sampled were still performing well and met their remedial action objectives (PASSiFy 2010). Additionally, the report affirms the viability of S/S as an effective long-term treatment as long as the nature of the soils and contaminated materials are known and an effective binder system is developed (Hills et al 2010).

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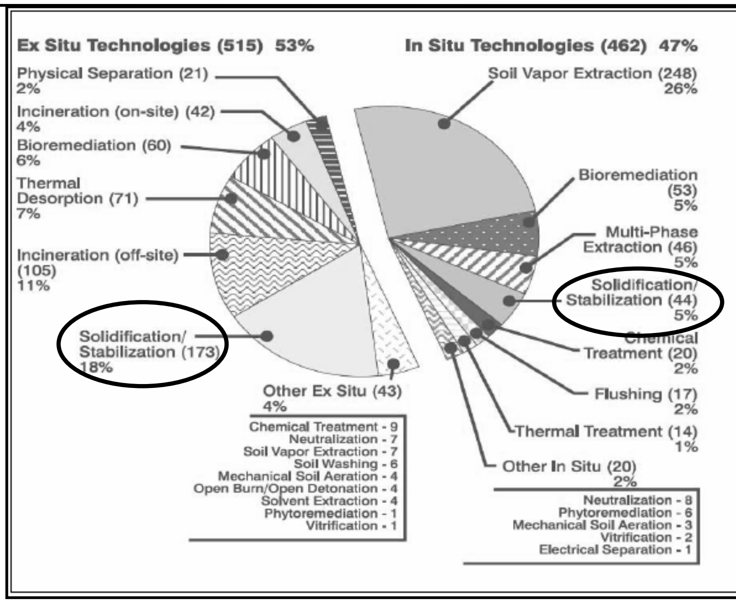
EPA Use of Solidification/Stabilization



EPA, 2009

According to EPA 2009 Annual Status Report (EPA. 2009a *Technology Performance Review: Selecting and Using Solidification/ Stabilization Treatment for Site Remediation*. EPA/600/R-09/148. Office of Research and Development), S/S has been selected as a source control remedy at more than 200 sites (period 1982 to 2005), representing about 23% of remedies selected at CERCLA Superfund remediation projects.

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Implementation Key Points

- Performance verification during implementation is critical to remedy success
- Sample collection, observation, and testing includes both consistency and compliance testing
- Extra samples are useful
- Performance data tracking is a useful tool to managing the construction process
- S/S is a viable long-term remedy and has been selected by EPA on numerous sites

No associated notes.

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No associated notes.

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Long-Term Stewardship and Case Study

- Importance of site model and review of project goals
- Long-term stewardship objectives
- Groundwater monitoring
- Peak Oil case study

No associated notes.

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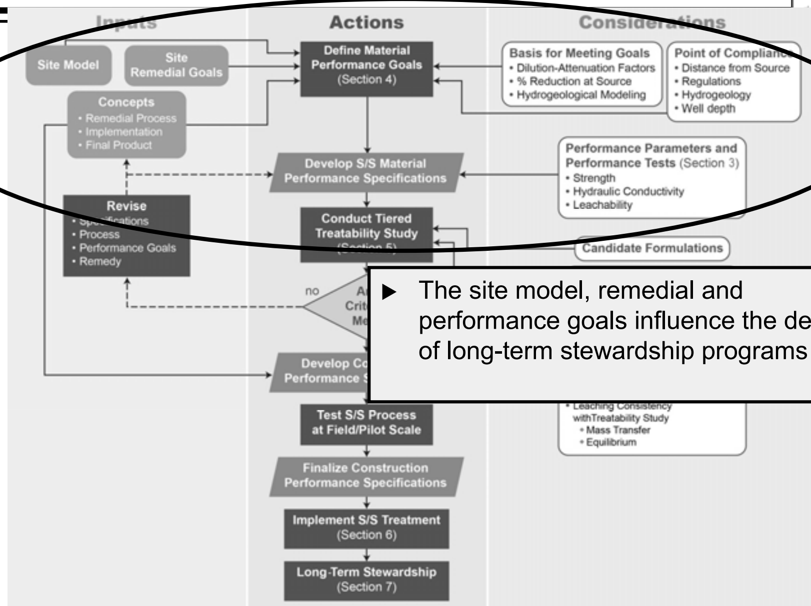
Importance Of Site Model And Goals



- The site model, remedial and performance goals influence the design of long-term stewardship programs

Remember where we started.

- First we constructed an accurate site model
- Then we set the overall project goals…example meeting drinking water MCLs
- And established a point, or points, of compliance, at which to accomplish the goals…such as the site boundary

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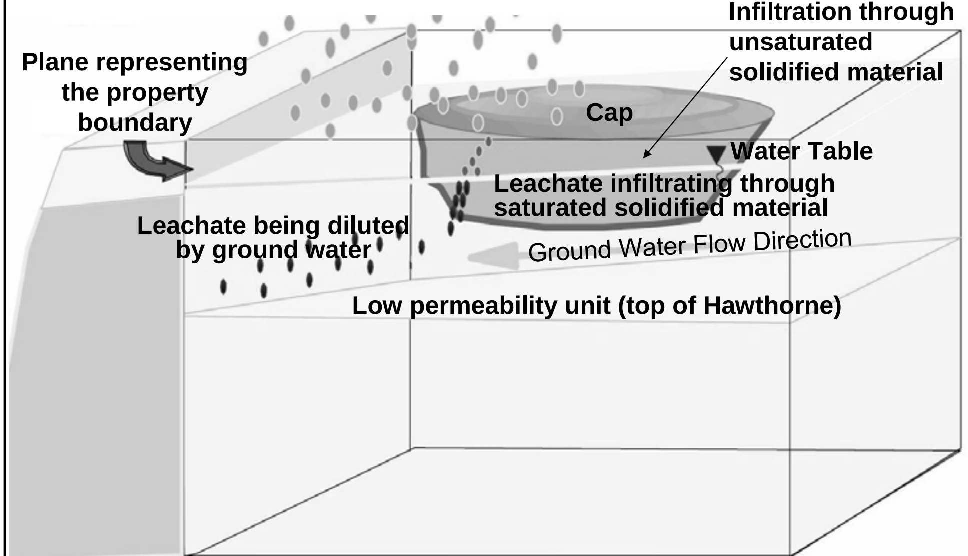
Conceptual Site Model



Schematic of conceptual model for development of performance goals at a designated point of compliance

S/S treatment achieves a low permeability monolith, with very low leaching potential, and a very small flux load of contaminant release to the environment.

However groundwater monitoring is often necessary to assure that :

- The monolith performs as designed, that the flux, or loading, of contaminants released remains very low over time

- That residual contamination decreases over time, thru Monitored Natural Attenuation (MNA) or other treatment, to meet goals at the point of compliance

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Long-Term Stewardship Objectives

- Confirm the S/S monolith is performing as designed
- Assure that groundwater meets targets

Before S/S Treatment

After S/S Treatment

Long-term stewardship usually includes monitoring of the groundwater impacted by contaminants prior to treatment, monitoring of institutional controls, monitoring and maintenance of engineering controls, financial assurances, and periodic review of the remedy effectiveness by the controlling environmental agency.

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Groundwater Monitoring Design

- Monitoring points
  - Compliance may be at one or more specific points or everywhere onsite within an impacted aquifer
- Monitoring parameters…usually the key COCs
- Monitoring locations
  - Site conditions
  - Potential changes in the groundwater flow regime induced by the treated material
  - Time of travel to compliance points
  - Contamination in groundwater prior to treating

The monitoring plan should be designed to meet the effectiveness and protectiveness evaluation objective of the monitoring program and should also provide a basis for decisions to modify or cease monitoring.

Groundwater cleanup criteria are a key component of the monitoring plan design and typically will have been established in the site remedy selection process. The criteria may include state or federal groundwater and/or surface water standards. However, it should be noted that because S/S is typically implemented as a source control remedy to minimize contaminant flux to groundwater, other technologies or approaches may be used in conjunction with S/S to meet site remedial goals.

Depending on state or Federal remedial goals, cleanup criteria may be applied at a site differently. The application of cleanup criteria can range from compliance at one or more specific points to compliance everywhere onsite within an impacted aquifer, demonstration of a percent reduction in concentration due to reduced flux from the treated material, and may be based on calculating acceptable attenuation between the treated material and the POC. Hydrogeologic modeling to simulate groundwater flow and concentration attenuation following treatment is sometimes used. For most sites, specific cleanup criteria for contaminants and the method to determine that these criteria are met by the S/S remedy, are determined by the regulatory agency.

An integral component of the monitoring plan design is determining the appropriate suite of contaminants and other parameters to monitor and evaluate for long-term performance of the S/S remedy. The contaminants of concern for groundwater or surface water will have been established prior to site remedy selection during site characterization and development of the site conceptual model, and therefore will follow through design and implementation and into the groundwater monitoring program.

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Frequency and Duration of Monitoring

- Superfund (CERCLA) requirements
  - Often quarterly to start, changing to annual
  - As needed for Five-Year Reviews
- State Programs
  - Usually follow CERCLA frequency for quarterly and annual monitoring
  - May vary in requirement for Five-Year Review periods
- Predictive modeling can be used to further identify appropriate monitoring frequency and duration

A typical frequency of monitoring at Superfund Sites includes quarterly following construction of the remedy, changing to annual after one or two years and includes Five-Year Reviews (EPA 2001) if contaminants are left /on site (as there are with S/S). For state programs, monitoring requirements usually follow the same frequency of monitoring used under the CERCLA program but may vary in the requirement of Five-Year Review periods. For example, the State of Texas only requires one Five-Year Review (G. Beyer, personal communication 2010). The State of Delaware requires monitoring only up to the point that eight quarters of groundwater data at the point of compliance demonstrate attainment of the remediation goals, after which time monitoring will not be required. Compliance can occur at any time before or after the first Five-Year Review (W. Reyes, personal communication 2010).

Monitoring frequency and duration requirements should be determined on a case-by-case basis, but be compliant with applicable state and Federal regulations. In keeping with the regulatory requirements, predictive modeling can be used to further identify appropriate monitoring frequency and duration. Modeling data may allow estimation of the length of time that concentrations in groundwater or surface water near the S/S treated material may exist above acceptable levels and to predict peak concentrations over time at specific points down-gradient from the S/S treated mass (EPRI 2009). Modeling can also take into consideration the different chemicals that may be present in the treated material in terms of their fate and transport characteristics. See Appendix C of document for case studies and information on modeling

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Interpreting Monitoring Data

- Evaluation of concentration trends over time should confirm
  - Decreasing or acceptable low concentration of COCs near the monolith
  - Decreasing concentrations at points of compliance
  - Achievement of GW goals over time at POCs
- Achievement of other criteria such as % reduction

Monitoring of wells are close to the monolith should demonstrate that contaminant flux from the monolith remains very low.

Monitoring of wells at the points of compliance should document eventual achievement of groundwater goals.

Sometimes wells are installed and monitored between the monolith and points of compliance to document gradually decreasing concentration of COCs

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Institutional and Engineering Controls

- Institutional controls
  - Environmental covenants to the property deed
- Engineering controls
  - Impervious caps
  - Vertical walls

Installing Vertical Wall With A Panel Cutter

EPA defines institutional controls (IC) as “non-engineering measures, such as administrative and/or legal controls, that help to minimize the potential for human exposure to contamination and/or to protect the integrity of a remedy by limiting land or resource use” (Environmental Data Standards Council 2006). ICs, which may be used when contamination is first discovered and when remedies are ongoing, may also be needed to meet regulatory requirements, when residual contamination remains onsite.

Common engineering controls (EC) are barriers that control downward or lateral migration of contaminants. Low permeability or evapo-transpiration caps prevent infiltration of surface runoff and rain. Low permeability vertical walls, keyed into an underlying clay, prevent lateral migration of contaminants .

The National Oil and Hazardous Substances Pollution Contingency Plan (NCP) (Title 40 Code of Federal Regulations Part 300 [40 CFR 300]) emphasizes that ICs, such as water use restrictions, are meant to supplement ECs during all phases of cleanup and may be a necessary component of the completed remedy; ICs will rarely be the sole remedy at a site.

Site reuse will have a significant influence on the design of the protective measures to ensure that any changes to land do not compromise the long-term structural and overall performance of the treated material. Requirements, such as the development of contaminated materials management plans, may also exist to protect site workers in the event of potential future excavation in the treated material. In general, ICs may include the establishment of environmental covenants to the property deed, and ECs may include the establishment of soil or impervious caps over the treated material and sometimes vertical barrier walls.

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Reuse Examples

Battery Recycling Site

Wildlife Habitat

Wood Preserving Site

Storage Yard

Top pictures show a battery recycling site heavily contaminated with lead and battery casings now being left as wildlife habitat.

Bottom pictures show a wood treating site heavily contaminated with creosote, pentachlorophenol and dioxins now being used as a materials storage yard.

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Peak Oil Superfund Site Case Study

Treatment of contaminated soil, sludge and ash

Case Study #2 in Appendix C. An additional case study is presented in Appendix C on the use of groundwater modeling (Case Study #1) and a third case study on a graded approach to modeling is also presented (Case Study #3).

Peak Oil Company conducted an oil re-refining operation at the property (OU 1) for used oils and lubrication fluids using an acid/clay purification and filtration process. Low-pH sludge and oil-saturated clay waste containing lead was generated and stored onsite in unlined lagoons. A 1986 removal action at the Peak Oil property consisted of removal of 4,000 cubic yards of acidic oily sludge from one of the three lagoons using a mobile incinerator and generating residual ash that remained onsite. The remaining two oily waste lagoons had been filled-in.

Lead was the primary COC detected in former lagoon areas at up to 2,950 milligrams per kilogram (mg/kg) and in the residual ash at an average 3,525 mg/kg. Other contaminants in low concentrations included volatile organic chemicals (VOCs) primarily toluene, ethylbenzene and xylenes; semi-volatile organic chemicals (SVOCs) primarily polycyclic aromatic hydrocarbons (PAHs); polychlorinated biphenyls (PCBs); inorganics notably barium, chromium and zinc. Other inorganics detected in former lagoon areas above background concentrations include low concentrations of arsenic, beryllium, cadmium, cobalt, copper, manganese, mercury and cyanide. A thick oily residue within the Surficial Sand unit was associated with the areas of the unlined lagoons.

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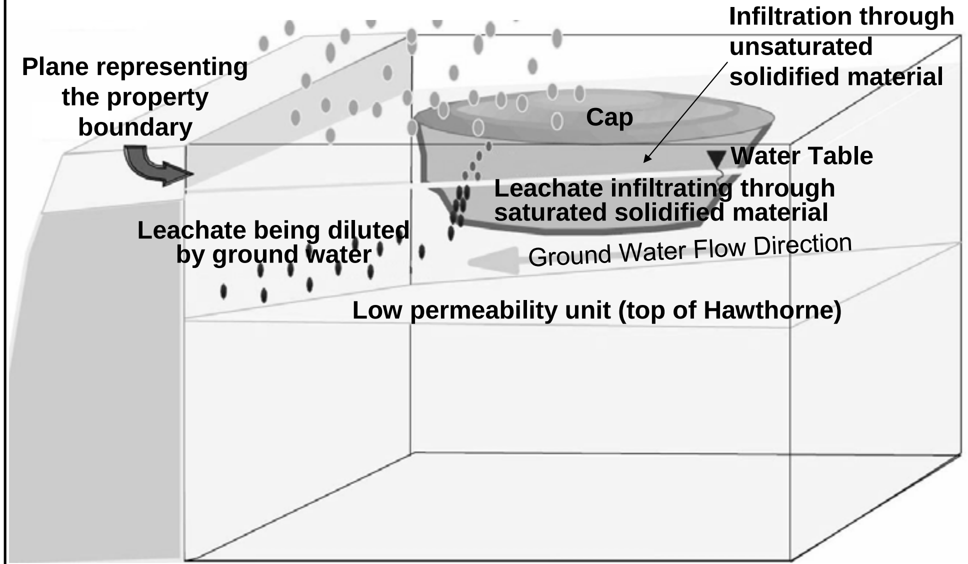
Post Remediation Peak Oil Site Model



• Schematic of conceptual post remediation site model was used for development of performance goals at a designated point of compliance (POC).

• Point of compliance was the down gradient site boundary

• Goal was to meet groundwater MCL for lead (15ug/l)

• The site specific groundwater flow volume and pathway were determined

• Groundwater modeling was then used to determine the acceptable flux(load) of lead that could be released to the groundwater and still meet the goal, considering the site specific amount of groundwater available for dilution

• Modeling considered the size and shape of the monolith, the local rainfall, and type of cap to determine infiltration, and the location of the monolith partly within the groundwater to determine the volume of leachate that would be produced

• Based on the expected volume of leachate and the acceptable flux to the environment, it was then possible to calculate the maximum concentration of lead in the leachate that would still allow for achievement of site groundwater goals

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Peak Oil Groundwater Modeling

- Objective
  - To determine allowable concentrations of lead in leachate from S/S treated material (SPLP test) to meet groundwater goals
- Groundwater goal
  - 15 μg/L lead
- Point of compliance at site boundary
- Result
  - 282 μg/L of lead allowable in the leachate to achieve 15 μg/L at the POC (18.8 dilution-attenuation factor)

Case Study #2 in Appendix C.

Groundwater modeling was conducted by US EPA for the Peak Oil Site to determine target concentrations for lead (SPLP test) for S/S treated material. The target concentrations were calculated to meet groundwater protection standards of 15 micrograms per liter (ug/l) for lead at the down gradient property boundary about 70 to 120 feet down gradient from the treated monolith.

Modeling considered the rainwater infiltration rate through the site cap and dilution of S/S treated material leachate by infiltration and groundwater flow volumes, and the ability to achieve the groundwater protection standards at the down gradient property boundary. EPA used the HELP3 (Hydrologic Evaluation of Landfill Performance) model which is an EPA model designed to assist in design of landfill profiles, predicting leachate mounding and evaluating leachate release to groundwater (Schroeder et al 1994). The initial modeling was conducted in late 1999, and additional modeling conducted in early 2000 to modify aspects of the vertical layers modeled and some input parameters.

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Peak Oil Construction Performance Parameters and Criteria

Action Levels	Lead at > 521 mg/kg		
S/S Mix Composition (from Treatability Testing)	6 wt% Portland Cement 1-2 wt% Triple Super Phosphate		
S/S Specifications	**Avg.**	**Allowance**	**Method**
Strength (USC; psi)	>50	None	ASTM D 1633
Hydraulic Conductivity (cm/s)	$<1x10^{-6}$	$1x10^{-5}$	ASTM D 5084
Leaching Lead (μg/L)	<282	<500	SPLP Method 1312

- All performance criteria at the site were met

Case Study #2 in Appendix C.

Remedial actions for both the Peak Oil included use of S/S treatment for contaminated soil, sludge, sediment and a residual ash pile for materials over 521 mg/l. Additional; engineering controls were added consisting of a clay slurry wall around the contaminated soil area and placement of a multimedia cap over the S/S treated material. Other controls included groundwater monitoring; institutional controls; and five-year reviews.

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Peak Oil Site Following Remediation

Case Study #2 in Appendix C.

Presentation Outline

- Technical Introduction
- Sections 1 & 2 – S/S Treatment Overview
- Section 3 – Performance of S/S Treated Materials
- Section 4 – Performance Specifications in the S/S Design and Implementation Process
- Q & A Break
- Section 5 – Treatability Studies
- Section 6 – Implementation
- Section 7 – Long-Term Stewardship and Case Study
- Wrap Up
- Q & A Break

No associated notes.

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Overall Course Summary

- S/S treatment has demonstrated long-term effectiveness for a number of contaminants
- Performance specifications - critical for S/S
- Treatability studies assess S/S treatment feasibility
- QA/QC, consistency, and compliance testing during implementation
- Long-term stewardship typically used with S/S
- Use guidance for understanding, developing, and using performance specifications to ensure success of S/S remedies

S/S treatment has been used for a number of contaminants and has been shown to be effective in the long-term. The performance must be tested prior to and during implementation and is typically monitored following implementation to ensure performance.

Control for release of contaminants

Performance specifications - critical for S/S

Key parameters - UCS, hydraulic conductivity and leachability

Leachability of particular concern for S/S

Role and selection of appropriate leaching tests for different phases of S/S

Thank you again for your attention and comments. I want to remind each of you that we are looking for your specific responses to many of the issues discussed today in our feedback form following this session.

Also, there are several resources and related documents included in the links to more resources on this page.

If you have any additional questions or comments, please feel free to contact myself or fill out a comment form on CLUIN.

Thank you and have a great afternoon.

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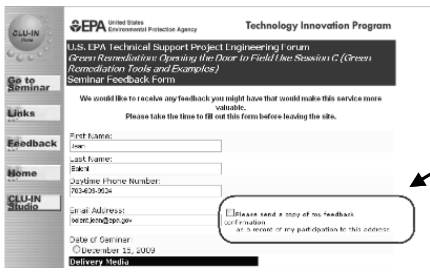
Thank You for Participating

- Second question and answer break
- Links to additional resources
  - http://www.clu-in.org/conf/itrc/SS/resource.cfm
- Feedback form – *please* complete
  - http://www.clu-in.org/conf/itrc/SS/feedback.cfm



Need confirmation of your participation today?

Fill out the feedback form and check box for confirmation email.

Links to additional resources:
http://www.clu-in.org/conf/itrc/SS/resource.cfm

Your feedback is important – please fill out the form at:
http://www.clu-in.org/conf/itrc/SS/feedback.cfm

The benefits that ITRC offers to state regulators and technology developers, vendors, and consultants include:

✓Helping regulators build their knowledge base and raise their confidence about new environmental technologies

✓Helping regulators save time and money when evaluating environmental technologies

✓Guiding technology developers in the collection of performance data to satisfy the requirements of multiple states

✓Helping technology vendors avoid the time and expense of conducting duplicative and costly demonstrations

✓Providing a reliable network among members of the environmental community to focus on innovative environmental technologies

How you can get involved with ITRC:

✓Join an ITRC Team – with just 10% of your time you can have a positive impact on the regulatory process and acceptance of innovative technologies and approaches

✓Sponsor ITRC's technical team and other activities

✓Use ITRC products and attend training courses

✓Submit proposals for new technical teams and projects