Introduction

In-Situ Solidification/Stabilization (ISS) of soil, sediment or waste material (impacted media) is often undertaken at contaminated sites to:

- Address risk to human health or the environment as part of immediate or long-term mitigation actions; and

- Address contaminant source material for which other remedies may be infeasible because of extremely high costs, long durations, or other technical constraints.

ISS is the process of blending treatment reagents into impacted media to impart physical and/or chemical changes that most often result in reduced mobility and leachability of constituents of concern (COCs), increased soil strength, and reduced permeability of the soil matrix. While grouped together in name, In-Situ Solidification binds the contaminants in a solid block to trap it in place, whereas In-Situ Stabilization uses chemical reactions that makes contaminants less likely to be leached into the environment.

Although ISS is an effective and potentially economically preferred technology, it can also create a large carbon footprint as measured by greenhouse gas (GHG) emissions. For example, ordinary Portland cement (PC), also known as Type I PC, has been one of the most common reagents used in ISS, and as much as approximately 1,800 pounds (lbs) of carbon dioxide (CO_2) are generated per ton of PC produced. A typical PC application rate of approximately 400 lbs of PC per cubic yard (CY) of ISS-treated soil translates to a GHG emission rate of approximately 360 lbs of CO_2 per CY treated for the PC production alone, or nearly an equal mass of amendment added to greenhouse gasses emitted. For reference, at this typical application rate, treating 10,000 CY of soil with ISS would translate to 3.6 million lbs. of CO_2 emitted, approximately equivalent to the emissions generated from ~200 homes in a single year, or 360 gasoline-powered passenger vehicles driven for one year.[1]

As such, minimizing the use of PC and/or substituting PC with less carbon-intensive amendments are opportunities to significantly reduce the carbon footprint of ISS remedies.

This guide is intended to inform the Project Manager about the concepts, tools and best management practices (BMPs) to reduce the environmental footprint of activities associated with assessing and remediating contaminated sites using ISS technologies. A checklist of BMPs is provided as **Attachment A** to this fact sheet for reference.

Core Elements of Green Remediation

- *Reducing total energy use and increasing renewable energy use*
- *Reducing air pollutants and greenhouse gas emissions*
- *Reducing water use and negative impacts on water resources*
- *Improving materials management and waste reduction efforts, and*
- *Enhancing land management and ecosystem protection*

Early and integrated project planning allows ISS approaches to set the stage for reduced consumption of natural resources, processes and infrastructures throughout site investigation, remediation and reuse and site management. ISS project planning should occur to ensure the most appropriate BMPs are selected for the project based on site conditions. Form A[2] (**Attachment B**) shall be used throughout remedial implementation of the project.

The following sections should be considered throughout the project.

BMPs related to ISS project scoping and pre-design investigation/assessment:

- Minimize overly conservative design assumptions, by establishing focused data quality objectives and identifying data gaps from the RI phase and collecting sufficient data to fully bound the areas to be remediated.

- Consult with a knowledgeable hydrogeologist/geo-chemist and a geotechnical engineer to understand and collect the necessary data to generate a fate and transport model of both existing and post-remedy conditions. These models will generate representative predictions at appropriate compliance points and help focus on priority areas for ISS to achieve cleanup goals.

- Develop compliance points, associated performance standards and supplemental mitigation steps.

- Identify vendors with operation centers local to the Site to minimize fuel consumption associated with travel to and from the Site.

- Collect soil permeability, strength and leachability data of untreated materials and mixed materials to assess untreated material performance. Leaching should use the Synthetic Precipitation Leaching Procedure (SPLP) or the most appropriate Leaching Environmental Assessment Framework, understanding that the Toxicity Characteristic Leaching Procedure is generally not representative.

- Estimate volume of swell and identify how and where swell can be managed, to increase on-Site reuse and reduce off-site disposal.

- Model fate and transport of COCs in groundwater during the RI to support the Feasibility Study (FS) and decisions related to long-term reasonable performance expectations.

- Assess future Site use options to determine if ISS is an appropriate remedy.

- Evaluate sensitive, local human and ecological receptors which require protection from COCs, traffic, noise, dust and odors during the implementation. An enhanced Community Air Monitoring Plan may be required.

- Characterize on-Site groundwater and surface water for possible use in ISS grout, to potentially replace or reduce potable water use. Consider flow rates, pH, hardness, and organic contents.

BMPs related to ISS Feasibility Study (FS):

- Evaluate lower-carbon alternatives to PC for In-Situ Solidification remedies through bench-scale treatability studies. This includes the use of cement-based binders incorporating waste additives such as ground granulated blast-furnace slag (GGBFS) and fly ash (FA). FA is a waste product from coal combustion; it is the finely divided residue that results from the combustion of ground or powdered coal and is transported by flue gases. Use of concrete made with Coal Combustion Products, such as FA, is also a top-five priority within the U.S. EPA Region 2 Clean & Green Policy: Touchstone Practices and Metrics[3]

  Lower-carbon stabilization agents such as biochar, ferrous sulfate, apatite, ground glass and clay minerals are also being actively researched and can be evaluated through site-specific treatability tests[4]. Another recent development is the general use of PC (ASTM C150 Type I)[5] has been replaced with Portland limestone cement (PLC), which is a type of blended cement specified under ASTM C59516 Type IL, or AASHTO M 24017. PLC is a blended cement with a higher limestone content; in the US and Canada it is made with Portland cement and between 5% and 15% fine limestone, which results in a product that has similar performance with Portland cement, but with a reduction in carbon footprint of 10% on average.

> In addition to remedial objectives to protect human health and the environment, it is the policy of NYSDEC to approach remediation projects such that the environmental footprint is minimized during a clean-up action. This concept, outlined in DEC Program Policy 31, is referred to as "Green Remediation"[6]. Additionally, Commissioner's Policy Sustainability, seeks to have NYSDEC continue its "lead by example" approach to accelerate and guide the transition to the low-carbon sustainable economy of the future[6].

- Bench testing test should be considered as part of the feasibility study followed by pilot testing as part of pre-design to optimize the mix design. Obtain samples of treated materials to assess homogeneity with different mixing techniques to minimize energy usage. Try different reagent blends and perform testing to determine and demonstrate performance prior to full-scale design and implementation.

- Add an evaluation criterion, specific to Sustainability metrics such as total energy consumption, GHG and other air emissions, water consumption and waste generation and disposal. Consider using footprint analysis tools such as SRT, SiteWise, and/or EPA's Spreadsheets for Environmental Footprint Evaluation (SEFA)[7]. The EPA's Power Profiler tool and Waste Reduction Model (WARM) may also be useful in footprint analysis and ISS construction alternatives evaluation[8]. Carry the chosen tool through to the design and implementation stage to compare actual metrics to baseline from the FS.

- Consider all resources used and use available guidance documents and experts to support Sustainability considerations and off-sets.

- Identify and incorporate Site Owner and Stakeholder programs/requirements for Sustainable remediation, including future potential redevelopment opportunities.

BMPs related to ISS design:

The design should include clear green/ sustainable BMPs to be implemented on materials, equipment, disposal/ recycling options, traffic, community impacts, and energy. Design and construction considerations should reference NYSDEC standard specification 01 89 29 – Green Remediation Practices. Sustainability Metrics footprint analysis tool used in the FS shall be refined during the design, and the associated Form A – Summary of Green Remediation Metrics shall be used through construction to track actual metrics for the footprint analysis.

- Include a standard specification to require supply chain and supporting service procurements adhere to sustainable requirements and provide certification.

- Sustainable material requirements, such as material generation CO_2 emissions should be screened in the design based on available information. Contractors should be required to identify and submit other options to be considered that have a lower carbon footprint or are more readily available locally (less transportation).

- Require the stripping and re-use of on-site topsoil and process cleared and grubbed material and vegetations for use to augment topsoil or as erosion control. Consider onsite manufacturing of topsoil through use of locally sourced industrial byproducts such as compost or silica-based spent foundry sands[9].

- Specify retrieval of native, noninvasive plants for later replanting.

- Specify geotextile bags or nets, when possible, to assure containment of excavated sediment during dewatering and to increase efficiency when handling and transporting the dewatered sediment.

- Choose geotextile fabrics/tarps made of recycled material.

- Specify hydraulic fluids that are biodegradable for operating equipment such as drill rigs[10].

- Specify chemicals or agents that are not harmful or hazardous to aquatic environments and the subsurface, are readily biodegradable, and/or can help to improve site geochemical conditions.

- Following the site assessment, incorporate the use of existing site groundwater and/ or the use of stormwater run-off (if possible) from within the remedial area for mixing.

- Refine swell management procedures to minimize off-site disposal. Consider if swell can be relocated to another area or if ground surface can be raised post remediation efforts. Planning usually is coordinated with post remediation design of future use at the site.

- Define ISS performance standards for the design, as well as methods of demonstrating compliance with the performance standards. For in-situ solidification, a typical design requirement is for the solidified mass to have a hydraulic conductivity (K) of 1.0×10^{-6} centimeters per second (cm/s) or less and would also result in an unconfined compressive strength of 20 pounds per square inch (psi), or higher dependent upon the determination of the future use of the site. Hydraulic conductivity and compressive strength can be measured by collecting samples of the solidified mass at a frequency determined in the design and allowing the samples to cure in a column prior to testing. For in-situ stabilization, performance standards are more likely related to the leachability of constituents of concern, as measured by analysis of treated soil for EPA SPLP concentrations.

Additional BMPs related to ISS remedial construction/implementation:

Continue to use metrics footprint analysis tool to track metrics throughout implementation, making use of the associated Form A and other materials tracked during construction.

Require the implementation of BMPs that are focused on maximizing reuse or recycling of excavated material and minimizing generation of waste during the process of excavating contaminated material, including:

- Reclaim and stockpile uncontaminated soil for use as infill or other purposes such as habitat creation.

- Salvage organic debris that is uncontaminated and free of pests or disease, for use as supplemental infill, mulch or compost.

- Salvage uncontaminated objects with potential recycle, resale, donation or onsite infrastructure value, such as steel, concrete and granite.

- Designate collection points for recycling single-use items such as metal, plastic and glass containers; paper and cardboard; and other consumable items.

References

[1] U.S. EPA, Greenhouse Gas Equivalencies Calculator. https://www.epa.gov/energy/greenhouse-gas-equivalencies-calculator

[2]NYSDEC Division 01, Section 01 89 29 Green Remediation Practices Standard Specification, Including Form A.

[3] US EPA. Touchstone Practices and Metrics Supporting EPA Region 2 Clean and Green Policy. 2016. Available from: https://www.epa.gov/greenerclean- ups/touchstone-practices-and-metrics-supporting-epa-region-2-clean-and-green-policy.

[4] Zhengtao Shen, Fei Jin, David O'Connor, and Deyi Hou Environmental Science & Technology 2019 53 (20), 11615-11617 DOI: 10.1021/acs.est.9b04990 Wang, L., Yu, K., Li, J.-S., Tsang, D.C.W., Poon, C.S., Yoo, J.-C., et al., 2018. Low-carbon and low-alkalinity stabilization/solidification of high-Pb contaminated soil. Chem. Eng. 351, 418427. Available from: https://doi.org/10.1016/j.cej.2018.06.118.

[5] ASTM C150/C150M Standard Specification for Portland Cement.

[6] New York State Department of Environmental Conservation. NYSDEC Program Policy: DER-31/Green Remediation (January 2011)

[7] U.S. EPA. Methodology & Spreadsheets for Environmental Footprint Analysis (SEFA). https://clu-in.org/greenremediation/methodology/

8 U.S. EPA. Greener Cleanups. Principles for Greener Cleanups. https://www.epa.gov/greenercleanups.

9 U.S. EPA. Beneficial Uses of Spent Foundry Sands. https://www.epa.gov/smm/beneficial-uses-spent-foundry-sands

10 General Services Administration. Sustainable Facilities Tool. Green Procurement Compilation. Lube, Oil, Hydraulic Fluid, & Grease. https://sftool.gov/greenprocurement/green-products/7/lube-oil-hydraulic-fluid-grease/0

Attachment B

In-Situ Solidification / Stabilzation Green Remediation Metrix

		Green Remediation Element Addressed				
Project Phase	**Best Management Practice**	**Energy/ GHG**	**Air**	**Water**	**Materials & Waste**	**Land & Ecosystems**
Site Investigation/ Assessment	Characterize on-Site groundwater and surface water for possible use in ISS grout, to potentially replace or reduce potable water use, consider flow rates, pH, hardness, organic contents, etc.	x		x		
	Assess future Site use options and evaluate sensitive, local human and ecological receptors which require protection from COCs, traffic, noise, dust and odors during the ISS implementation.					x
	Collect sufficient data to bound horizontal and vertical limits of the ISS treatment zone, to minimize the overall remedy footprint. Don't leave data gaps in delineation that could result in unnecessary treatment beyond what is needed to meet the cleanup goals.	x	x	x	x	x
Feasibility Study / Treatability / Bench Testing	Identify local sources of reagents, availability, quantities, seasonality, ISS characteristics, and potential leaching concerns, with a focus on alternate reagents produced with less energy and waste materials (another projects' waste can be a green reagent) and obtain samples for testing. Local companies and/or sources will be submitted to NYSDEC as part of a database of sustainable material sources to share with other project teams.	x			x	
	Perform screening level bench studies to assess treatability related to required permeability, strength and leachability studies. Evaluate lower carbon ISS amendments for bench-scale, laboratory treatability studies.	x				
	If lower carbon ISS amendments show promise at bench-scale and are commercially available, perform a pilot test to further optimize the mix design and reagent use and exhume treated materials to assess homogeneity with different mixing techniques to minimize energy usage. Try different reagent blends and perform testing to determine and demonstrate performance prior to full-scale.	x				
	Add an evaluation criterion, specific to Sustainability metrics such as total energy consumption, GHG and other air emissions, water consumption and waste generation and disposal to evaluate ISS against other remedial technologies.	x	x	x	x	x
Remedial Design and Implementation	Detail review of RI data to identify any remaining data gaps. Complete Data Gap anlysis to avoid over conservative design. Conduct Fate and Transport Model to potential aid in focuses on priority areas for ISS.	x	x	x	x	x
	Determine if funding is available to offset short-term sustain- ability costs with long-term benefits from utility companies and or state and federal government.	x				
	The design should include clear green/sustainable BMPs to be implemented on materials, equipment, disposal/ recycling options, traffic, community impacts, and energy and follow Form A from NYSDEC Specification 01 89 29 Green Remediation Practices, tracked monthly.	x	x	x	x	
	Include a standard specification to require that supply chain and supporting service procurements adhere to sustainable requirements and provide certification				x	
	Require the stripping and re-use of on-site topsoil and unimpacted soil that may be located above the ISS treatment zone. Consider onsite manufacturing of topsoil through use of locally sourced industrial byproducts such as compost or silica-based spent foundry sands.				x	x
	Following the site assessment, incorporate the use of existing site groundwater and/ or the use of stormwater run-off (if possible) from within the remedial area for mixing.			x		
	Refine swell management procedures in order to minimize off-site disposal. Evaluate if swell can be relocated to another area or can ground surface be raised post remediation efforts.				x	x
	Consider future site use during remediation design, may reduce requirements for soil strenth, backfill, final finishes (wild flowers instead paved/gravel areas).				x	x
	Reclaim and stockpile uncontaminated soil for use as infill or other purposes such as habitat creation.				x	x
	Salvage organic debris that is uncontaminated and free of pests or disease, for use as supplemental infill, mulch or compost.				x	x
	Salvage uncontaminated objects with potential recycle, resale, donation or onsite infrastructure value, such as steel, concrete and granite.	x			x	

Attachment 1 - Form A
Summary of Green Remediation Metrics

Site Name: ______________________________ Site Code: _____________ Operable Unit: _______
Address: ____ City: ________________________________
State: _____________ Zip: ___________ County: _______________

Reporting Period
Contract Period From: _____________To: ______________
Reporting Period From: _____________To: ______________ Is this a Final Report? Yes ☐ No ☐

Contact Information
Preparer's Name: _______________________________ Phone No.: __________________________
Preparer's Affiliation: ____________________________ Company Code: ______________________
Contract No. ____________________________________

Materials & Waste Generation: Quantify the materials used or consumed and the management of waste generated on-site.

	Current Reporting Period (Include Units)	Total to Date (Include Units)
Materials Brought to the Site		
• Topsoil		
• Fill		
• Silt Fence		
• Silt Logs		
• Aggregate Base Course		
• Geotextile		
• Solidification Additives		
• Activated carbon		
• Other:		
• Other:		
• Other:		
• Other:		
• Other:		
• Other:		
• Other:		
Total Wastes Generated On-Site		
• Remedy Generated Waste		
• Contractor Generated Waste		
• Other:		
• Other:		
• Other:		
• Other:		
• Other:		
• Other:		
• Other:		

Provide a description of any implemented waste reduction programs appropriate for this project in the space provided on the certification page.

Recycled and Bio-Based Content in Imported Products and Materials: Quantify all materials and products imported to the site, including cost of materials/dollar values. Provide total percentages of recycled and bio-based of products and materials.

List Products and Materials Below	Total $ Value Provided	Total Percent of Recycled Content	Total Percent of Bio-based Content

Provide additional descriptions, as necessary, in the space provided on certification page.

Solid Waste Disposal and Diversion: Quantify all solid wastes generated, and indicate whether material was disposed or diverted for recycling or reuse.

Solid Waste Material	**Date**	**Disposed or Diverted**	**Volume** (Ton or CY)	**Disposal/Recycling Facility Name**	**Comments** (if not diverted, state why)
TSCA Contaminated Sediment					
Non-TSCA Contaminated Sediment					
Cleared Vegetation					
Spent Granular Activated Carbon					
Monitoring Well Removal Debris					
Other:					
Other:					
Other:					
Other:					
Other:					
Other:					

Provide descriptions in the space provided on the certification page of all wastes that were redirected for recycling or reuse. Indicate full names and addresses of facilities.

Energy Usage: Quantify the amount of energy used on-site and portion of that voluntarily derived from renewable energy sources.

	Current Reporting Period (KWh)	Total to Date (KWh)
Total electricity usage		
Of that total amount, provide quantity:		
• Derived from renewable source (i.e., solar, wind)		
• Other:		

Provide descriptions in the space provided on the certification page of all reported energy use reduction programs appropriate to this project, including use of electricity derived from renewable sources.

Water Usage: Quantify the volume of water used on-site from difference sources.

	Current Reporting Period (Gallons)	Total to Date (Gallons)
Total quantity of water used on-site		
Of that total amount, provide the quantity obtained from:		
• Public potable water supply		
• Surface water		
• On-site treated groundwater		
• Reclaimed treated water		
• Collected or diverted storm water		
• Re-Injected groundwater		
• Other:		
• Other:		

Provide descriptions in the space provided on the certification page of any reported water use reduction programs applied. Please note if reused/injected groundwater is pre-treated.

Emissions: Quantify the distance traveled for delivery of supplies and removal of waste.

	Current Reporting Period (Miles)	Total to Date (Miles)
Off-site mobile fuel combustion		
Other:		

Provide descriptions in the space provided on the certification page of practices such as use of local vendors within 150 miles of the site and on-site stationary fuel use reduction programs.

Quantify the number of hours that diesel and other equipment with the potential to emit hazardous air pollutants (HAPs) or greenhouse gas (GHG) emissions was operated on-site.

	Current Reporting Period (Hours)	Total to Date (Hours)
On-site diesel excavation/construction equipment usage		
Other on-site processes generating emissions		
Other:		

Quantify the VOC emissions from active remediation systems on-site.

	Current Reporting Period (lbs VOCs emitted)	Total to Date (lbs VOCs emitted)
Operating soil remediation equipment		
Operating groundwater remediation equipment		
Other:		

Provide descriptions in the space provided on the certification page of the type of equipment used, rating, emission control devices used and other means to reduce emissions.

Land and Ecosystem: Quantify the amount of land and/or ecosystems disturbed by construction and the area of land and/or ecosystems restored to a natural condition.

	Current Reporting Period (Acres)	Total to Date (Acres)
Total land area disturbed		
Total land area restored		
Increase in area for storm water infiltration (vs pre-disturbed conditions)		
Increase in area of native species plantings (vs pre-disturbed conditions)		
Other:		

Quantify the amount of land and/or ecosystems remediated.

	Current Reporting Period (Acres)	Total to Date (Acres)
Total area of land impacted by contamination		
Total area of land remediated to unrestricted use		
Total area of land remediated to other future site use		

Additional Comments on Green Remediation Programs Implemented: *Provide descriptions in the space provided of other green remediation practices performed during the project.*

Descriptions of green remediation programs reported above (Attach additional sheet if needed)
Materials and Products Imported:
Waste Generation:

Descriptions of green remediation programs reported above (Attach additional sheet if needed)
Recycled and Bio-Based Content in Imported Products and Materials:
Solid Waste Disposal and Diversion:
Energy Use:
Water Use:
Emissions:
Land and Ecosystem:
Other:

CERTIFICATION BY CONTRACTOR
I, ____________________________ (**Name**) do hereby certify that I am _______________________ (**Title**) of the Company/Corporation herein referenced and contractor for the work described in the foregoing application for payment. According to my knowledge and belief, all items and amounts shown on the face of this application for payment are correct, all work has been performed and/or materials supplied, the foregoing is a true and correct statement of the contract account up to and including the last day of the period covered by this application.
____________________ ____ **Date** **Contractor**