The Move Towards Green and Sustainable Remediation – Implications for Soil and Groundwater Remediation

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ABSTRACT

Making remediation efforts more "sustainable" or "green" has recently become a topic of great interest in the remediation community. It has spawned new organizations, areas of discussion, and guidance documents around sustainable remediation or green remediation. Green remediation can be thought of as a subset of sustainable remediation and is mostly focused on reducing the environmental footprint of cleanup effort. Sustainable remediation includes both social and economic considerations, in addition to environmental.

Application of both green and sustainable remediation (GSR) may involve two primary activities. The first is to develop technologies and alternatives that are greener or more sustainable. This can also include making existing remediation approaches greener or more sustainable. The second is to include GSR criteria in the evaluation of remediation alternatives and strategies. In other words, to include these GSR criteria in the evaluation of alternatives in a feasibility study. In some cases, regulatory frameworks allow the flexibility to include GSR criteria into the evaluation process (e.g., state cleanup programs). In other cases, regulations allow less flexibility to include the evaluation of GSR criteria (e.g., CERCLA). New regulatory guidance and tools will be required to include these criteria in typical feasibility studies.

INTRODUCTION and DEFINITIONS

The US EPA has defined green remediation as:

> The practice of considering all environmental effects of remedy implementation and incorporating options to maximize net environmental benefit of cleanup actions [1].

The US EPA Office of Solid Waste and Emergency Response (OSWER) provided additional clarification in 2009 in a document called Principles for Greener Cleanups [2]. OSWER states that:

> We can optimize environmental performance and implement protective cleanups that are greener by increasing our understanding of the environmental footprint, and when appropriate, and taking steps to minimize that footprint.

Sustainable remediation is typically defined as being broader than green remediation. The Sustainable Remediation Forum (SURF), a group of remediation professionals that has banded together to look into sustainable remediation) has defined sustainable remediation broadly as:

> A remedy or combination of remedies whose net impact on human health and the environment is minimized through the judicious use of limited resources. In order to minimize impacts we will embrace sustainable approaches to remediation that provide a net benefit to the environment. To the extent possible, these approaches will (1) minimize or eliminate energy consumption or the consumption of other natural

resources, (2) reduce or eliminate releases to the environment, especially to the air, (3) harness or mimic a natural process, (4) result in the reuse or recycling of land or otherwise undesirable materials, and (5) encourage the use of remedial technologies that permanently destroy contaminants [3].

SURF, and many other organizations and companies, have adopted the tenants of the "triple bottom line" of sustainability which include environmental, social, and economic factors [4]. Figure 1 illustrates this concept. In terms of the triple bottom line, developing sustainable remediation systems seeks to maximize the net positive impact to all three categories. SURF addressed this issue in Integrating Sustainable Principles, Practices, and Metrics into Remediation Projects [3]. This paper also discusses the current status of sustainable remediation, concepts and practices, impediments and barriers, a vision for sustainability, and case studies. It was the first, and to this date only, comprehensive review of sustainability in the remediation industry.

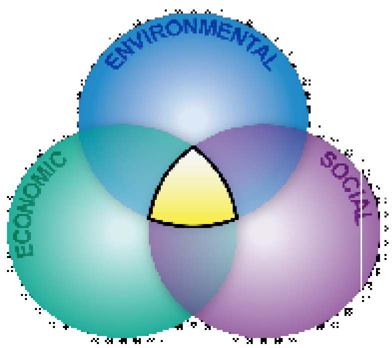

Fig. 1. Sustainability Triple Bottom Line

The Interstate Technical and Regulatory Council (ITRC) and the American Society of Testing and Materials (ASTM) have also recently undertaken efforts to help guide the discussion on green and sustainable remediation. ITRC is developing a technical guidance document that will provide an overview of current practices and challenges in applying GSR. ITRC will then produce a technical and regulatory guidance document that will provide guidance on how to implement GSR and it will sponsor training events. ASTM is developing a standard for green remediation and is titling their effort, "Standard Guide for Green and Sustainable Corrective Action." Both the ITRC and ASTM teams have decided to specifically make their scope broader than just the environmental footprint and will also include both the social and economic aspects of sustainability. Both of these efforts are likely to develop over the next year or two.

The importance of considering GSR to US Federal agencies can be found in several Executive Orders. For example, in October 2009 an Executive Order titled, "Federal Leadership in Environmental, Energy, and Economic Performance" was issued calling for all federal agencies to increase energy efficiency, reduce their greenhouse gas emissions, conserve and protect water resources, eliminate waste, and prevent pollution. A number of agencies developed policies even before this order was issued. For example, the Department of Defense (DoD) restoration program policy was spelled out in an August 10, 2009 policy statement [5]. This policy, titled "Consideration of Green and Sustainable Remediation Practices in the Defense Environmental Restoration Program," calls on the DoD components to develop briefing material by December 2009 on efforts to implement green and sustainable remediation.

The US Navy provides additional details on what sustainable remediation is and how it can be applied in the Sustainable Environmental Remediation Fact Sheet [6].

Very simply, the efforts to make soil and groundwater remediation efforts greener and more sustainable can be thought of as having two main areas of focus:

1. Develop and implement remediation technologies and approaches that are greener or more sustainable. This may include optimizing an existing remediation system to be greener or to include greener and more sustainable technologies in feasibility studies.

2. Include green and/or sustainable criteria in the evaluation of alternative remediation technologies and approaches. This will take the development and application of calculation tools and methods to evaluate the net sustainability impacts of remediation projects and integrate these impacts into regulatory decision making processes.

GREENER REMEDIATION TECHNOLOGIES AND APPROACHES

There are two basic ways to make a remedy greener or more sustainable. The first is to use technologies that are inherently greener. The second, is to try to make a given remediation technology as green as possible.

Inherently green remediation technologies may include technologies that mimic or use natural processes. These may include:

- Use of wetland or passive bioremediation approaches for treatment of extracted groundwater.

- In situ groundwater bioremediation or ex situ soil bioremediation with application of waste products to mimic natural degradation.

- Phytoremediation for control of groundwater or removal of contaminants.

- Monitored natural attenuation to allow the ongoing natural process to manage the contamination.

Figure 2 is an illustration of a solar powered, passive bioreactor system. This type of system could be filled with organic waste material, such as mulch and scrap iron. It could be used for the treatment of chlorinated solvents, nitrate, hexavalent chromium, and possibly uranium.

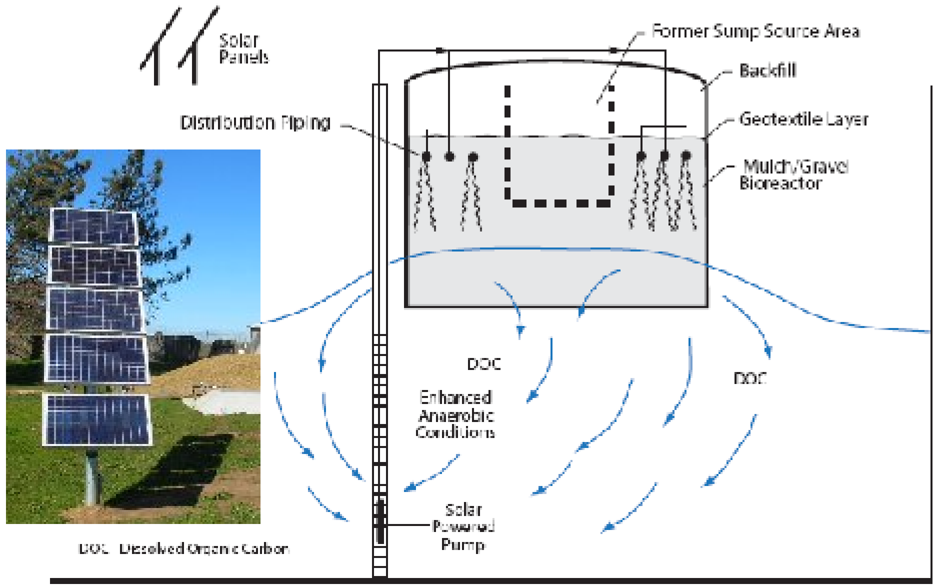

Fig. 2. Passive, Solar Powered Bioreactor

It should be noted although these technologies can be considered as inherently green/sustainable, they may not be either green or sustainable in a given site setting, or they may not rate highly on other selection criteria. For example, wetland or phytoremediation approaches typically require a relatively large land area, that may not be economical to acquire or it may take a valuable land asset away from a more sustainable use.

To make a given remediation technology greener or more sustainable, the following factors are typically addressed.

- Reduce energy use and increase energy efficiency.
- Use renewable energy sources.
- Reduce air emissions of green house gasses (e.g. carbon dioxide), as well as other pollutants (e.g. particulate matter).
- Reduce fresh water consumption and maximize water reuse.
- Maximize recycling, reuse, and reduction of materials including wastes.
- Reduce impacts on ecosystems and ecological receptors.
- Reduce the negative impact on human use of resources such as land, water and recreation.

The application of these approaches to an existing groundwater remediation system is illustrated by the efforts that the Air Force Center for Engineering and the Environment (AFCEE) has undertaken at the Massachusetts Military Reservation (MMR) [7]. MMR, which is located on Cape Cod, is one of the U.S. DoD's largest and most complex cleanup sites. At the site, the AFCEE team monitors 12 groundwater plumes and operates and maintains nine groundwater granular activated carbon, pump-and-treat systems. These treat 14-15 million gallons per day of contaminated water using more than 100 extraction and reinjection wells. In addition to restoration, the team stresses program-wide sustainability and optimization. For more than six years, this program has focused on reducing energy, improving carbon utilization, and optimizing plume capture and long-term monitoring programs. Examples of MMR's sustainable remediation efforts include:

- Installing variable-frequency drives, allowing for elimination of booster pumps, premium efficiency motors, and downsizing pump motors.
- Using Air Force owned and self-performed direct push technology for drilling, resulting in reduced costs and waste generation, and minimizing impacts on the environment and community.
- Monitoring nearby wetlands and water bodies to assess and minimize long-term impacts.
- Implementing beneficial reuse of treated water for VA cemetery irrigation and heating/cooling of several potential facilities.
- Using an innovative, 1,200-square-foot, zero-valent iron geochemical barrier that passively removes approximately 67 percent of the phosphorus discharging into a pond, thereby improving the trophic health of the pond.
- Increasing use of biofuels and environmentally sensitive hydraulic oil in fleet vehicles.
- Using passive/no-purge sampling techniques rather than techniques using pumps, resulting in reduced energy use and decreased waste generation.
- Switching power supply to suppliers that purchase renewable energy certificates from renewable energy sources
- Conducting energy audits and implementing energy-conservation measures such as use of efficient lighting, occupancy sensors, and programmable thermostats.
- Incorporating sustainability considerations into a feasibility study and tracking sustainability initiatives for the Installation Restoration Program.

In addition, a 1.5-megawatt wind turbine was installed by AFCEE at MMR in 2009. It is projected to reduce the energy consumption for all the remediation systems currently in place by 25 to 30 percent, eliminating 6.7 million pounds of CO2 annually. These optimization and sustainability efforts on the part of the program over the last six years have resulted in an estimated savings of approximately $4 million.

In order to make remedies that include excavation greener, the US EPA has developed a "Green Remediation: Best Management Practices for Excavation and Surface Restoration" (US EPA, 2008). This guidance document provides a number of practices that can be undertake to reduce the environmental footprint of soil remediation using excavation. Some of these include using biofuels in the excavation and hauling equipment, using surgical excavation methods to remove and dispose of only the amount of soil required to meet the remedial objectives, and covering excavation areas to reduce air emissions with biodegradable fabric that can also serve as a substrate for favorable ecosystems.

GREEN/SUSTAINABLE CRITERIA IN ALTERNATIVE SELECTION PROCESS

Many of these greener or sustainable remediation approaches may seem inherently green, but it is not always easy to discern which of a number of remediation alternatives will be greener or more sustainable. Consequently, tools to calculate GSR impacts and methods to help incorporate GSR criteria into the evaluation of alternatives are needed. These criteria can be integrated into a CERCLA feasibility study (provided the criteria can be mapped to existing decision criteria), or in an evaluation performed as part of a Remedial Process Optimization (RPO) of an existing system.

A critical aspect of these tools is the selection of the most appropriate metric (or criteria) to evaluate for a particular site. With consideration of the triple bottom line of sustainability, there are a wide range of sustainability criteria that could be considered, for example cost (economic), natural resource impacts (environmental) and job creation (social). The SURF paper (referenced above) presented a comprehensive list of sustainability metrics that can be considered for each component of the triple bottom line. However, if the narrower, green remediation aspects are only to be evaluated, the criteria can be focused on those that impact the environmental foot print. In the August of 2009 US EPA OSWER policy for greener cleanups, the EPA set out five elements of green cleanup assessment to assist with the evaluation and documentation of the selection and implementation of protective cleanup activities. The elements, which can also be considered metrics, are summarized in Table 1 and also include best practices associated with each element.

Table 1 – Greener Cleanup Elements (metrics)

1. Minimize Total Energy Use and Maximizes Use of Renewable Energy	
	Minimize energy consumption (e.g. use energy efficient equipment)
	Power cleanup equipment through onsite renewable energy sources
	Purchase commercial energy from renewable resources
2. Minimize Air Pollutants and Greenhouse Gas Emissions	
	Minimize the generation of greenhouse gases
	Minimize generation and transport of airborne contaminants and dust
	Use heavy equipment efficiently (e.g. diesel emission reduction plan)
	Maximize use of machinery equipped with advanced emission controls Use cleaner fuels to power machinery and auxiliary equipment Sequester carbon onsite (e.g., soil amendments, revegetate)
3. Minimize Water Use and Impacts to Water Resources	
	Minimize water use and depletion of natural water resources
	Capture, reclaim and store water for reuse (e.g. recharge aquifer, drinking water irrigation)
	Minimize water demand for revegetation (e.g. native species)
	Employ best management practices for stormwater
4. Reduce, Reuse and Recycle Material and Waste	
	Minimize consumption of virgin materials
	Minimize waste generation
	Use recycled products and local materials
	Beneficially reuse waste materials (e.g., concrete made with coal combustion products replacing a portion of the Portland cement)
	Segregate and reuse or recycle materials, products, and infrastructure (e.g. soil, construction and demolition debris, buildings)
5. Protect Land and Ecosystems	
	Minimize areas requiring activity or use limitations (e.g., destroy or remove contaminant sources)
	Minimize unnecessary soil and habitat disturbance or destruction
	Minimize noise and lighting disturbance

The evaluation of these types of metrics for various projects has been done for a number of years and is called Life Cycle Assessment (LCA). Frame works for performing LCAs is available from in ISO (the International Organization for Standardization), primarily ISO 14040 and ISO 14044. Life Cycle Assessment (LCA) is a standardized method to determine the environmental and human health impacts of products or services (ISO 14040 series). To date, LCA has been used primarily by businesses to benchmark operations or evaluate and compare products or alternative processes. LCA is increasingly being used at a strategic level for business development, policy development, and education. In ISO 14040, LCA is defined as the "compilation and evaluation of the inputs, outputs, and potential environmental impacts of a system throughout its life cycle." A product's life cycle is generally broken down into stages, including transportation. Activities such as remediation would be made up of similar steps, such as (1) raw materials extraction and processing; (2) intermediate materials production and consumption; (3) processes and activities on-site, including maintenance; (4) end-of-life management, including reuse, recycling, and disposal. In terms of the ISO standard, the term "product" also include services (e.g.,. remediation) [3].

A life-cycle based perspective helps improve entire systems by avoiding decisions that fix one environmental problem but cause another unexpected or costly environmental problem. When used properly, life-cycle thinking can facilitate better designs and prevent burden shifting (media, geography, or time). Life-cycle thinking helps us recognize how our selections are one part of a whole system so we can balance trade-offs and positively impact the economy, the environment, and society [3].

Table 2 illustrates a portion of the output from a fairly simple evaluation of two alternatives for the upgrade of a groundwater remediation system that is removing hexavalent chromium. The first alternative adds bioremediation of a source zone to an existing pump and treat system. The second alternative adds excavation of the source zone and additional extraction wells to an existing pump and treat system that uses ion exchange to remove the chromium. The systems are expected to operate at least 15 years. The values shown are the total emission over that period. In this case it appears that the bioremediation actually increases the greenhouse gas emissions. This is primarily due to the power for the additional extraction wells that would be operated. However, the waste produced for the source zone excavation is much greater in the second case. Part of the challenge with this type of analysis is finding the input parameters for all of the operations. For this case, greenhouse gas emissions for the production of bioremediation substrate that might be used (cheese whey) and ion exchange resins are not easy to find, and similar products had to be used. Care must also be taken when allocating green house gas emissions for power production, because they can vary widely, depending on the source of the power.

Table 2 – Example Partial LCA Output for Groundwater Remediation

	Greenhouse Gases (tons CO_2 equivalent)	Waste (tons)	Fuel Consumption (tons)
Combined P&T and Bioremediation			
Construction (Including well installation)	273	19	21
Ion Exchange System Operation	804	512	41
Bioremediation Operation	3,270	NA	2
Power	38,045	NA	NA
Other Fuel Use	159	NA	3
Excavation and Disposal	NA	NA	NA
Total	**42,551**	**532**	**67**
Pump and Treat			
Construction (Including well installation)	271	22	24
Ion Exchange System Operation	1,952	1,244	96
Bioremediation Operation	NA	NA	NA
Power	31,514	NA	NA
Other Materials	368	NA	9
Excavation and Disposal	NA	97,618	NA
Total	**34,105**	**98,884**	**129**

Incorporating these metrics into a CERCLA decision documents and alternative evaluations can also be a challenge. There are currently no standard approaches. The first issue is how to incorporate, or map the GSR metrics or elements to the standard nine CERCLA criteria. Many of the standard metrics can be included in the Short Term Effectiveness criteria, but not all. For example, the impacts of green house gas emissions may be considered more of a long term impact.

The second issue it how to use these GSR metrics, along with the other nine CERCLA criteria in selecting the preferred remediation approach. Various decision analysis tools can assist with this evaluation. These can range from simple qualitative comparisons to more detailed semi-quantitative approaches. Careful consideration of how to quantitatively compare the metrics is required for the semi-quantitative approach. For example, how do you compare tons of greenhouse gas emitted compared to a human health excess cancer risk value? Some type of normalizing and weighting procedure it required. Standard tools for this type of analysis are not currently available, but maybe within the next few years.

CONCLUSIONS – IMPLICATIONS FOR SOIL AND GROUNDWWATGER REMEDIATION

This new interest in GSR provides a number of challenges for remediation professionals performing soil and groundwater remediation projects. But it also provides new opportunities to think differently and look at the bigger picture of the overall benefit we are providing with our remediation projects.

Many of these challenges are discussed above. Probably the most significant is just trying to stay on top of the ever changing landscape of products, tools, and guidance documents coming out of various groups, the US EPA, and a few states. Within the next year or two, the rapid pace of change and document production should slow down.

The opportunities from the move towards GSR are very real. They will help us make remedial actions truly more beneficial to the environment and to society. They will also allow (or force) remediation practitioners to think outside of the usual realm of approaches to find newer and more beneficial technologies.

Whether the coming of GSR is viewed as providing opportunities or only challenges, it is coming. Given the 2009 Executive Order, GSR cannot be ignored.

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