Overview of Green and Sustainable Remediation for Soil and Groundwater Remediation - 12545

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ABSTRACT

Making remediation efforts more "sustainable" or "green" is a topic of great interest in the remediation community. It has been spurred on by Executive Orders from the White House, as well as Department of Energy (DOE) sustainability plans. In private industry, it is motivated by corporate sustainability goals and corporate social responsibility. It has spawned new organizations, areas of discussion, tools and practices, 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 efforts. 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., Comprehensive Environmental Response Compensation, and Liability Act (CERCLA)). New regulatory guidance and tools will be required to include these criteria in typical feasibility studies.

INTRODUCTION and DEFINITIONS

The definitions and terms used in the discussions of GSR can be confusing, in part because they are not all consistent and some overlap. First, GSR can be considered as an umbrella term. The Interstate Technology and Regulatory Council (ITRC) defines GSR as [1]:

> A remedy or combination of remedies whose net benefit to human health and the environment is maximized through the judicious use of resources and the selection of remedies that consider how the community, global society, and the environment would benefit.

Green remediation can be considered a subset of GSR, in that it focuses on environmental impacts. The US Environmental Protection Agency (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 [2].

The US EPA Office of Solid Waste and Emergency Response (OSWER) provided additional clarification in 2009, in a document called Principles for Greener Cleanups [3]. 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, taking steps to minimize that footprint.

Sustainable remediation is often used synonymously with GSR, in that it considers not just the environmental impacts or benefits, but also the economic and social benefits. Sustainable remediation can be thought of in terms of 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 optimize the net positive impact to all three categories. Again, in contrast, green remediation only considers the environmental impacts.

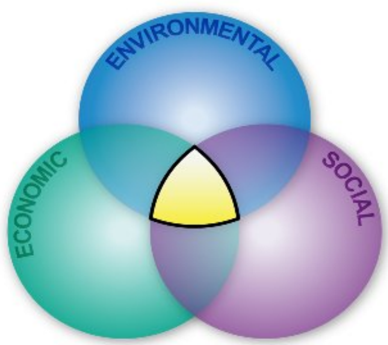

Fig. 1. Sustainability Triple Bottom Line

The importance of considering GSR to US Federal agencies can be found in several Executive Orders. For example, in October 2009, an Executive Order (EO) titled, "Federal Leadership in Environmental, Energy, and Economic Performance" (EO 13514) 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], titled "Consideration of Green and Sustainable Remediation Practices in the Defense Environmental Restoration Program." The Department of Energy (DOE) has not developed a policy specific to GSR, but it has a broader policy on sustainability. The Strategic Sustainability Performance Plan was issued in September 2010 [6]. In the plan it states that DOE will consider opportunities to deploy more sustainable deactivation and decommissioning (D&D) technologies as well as to continue to incorporate green remediation practices into its environmental cleanup program.

AGENCY and ORGANIZATION GSR RELATED ACTIVITIES

A wide variety of government and non-government entities have been active in the past several years on GSR related activities. The ITRC provides a comprehensive summary of these [1]. The following is a brief summary, with reference to key documents.

USEPA: USEPA has established a website for green remediation (http://www.clu-in.org/greenremediation/) and keeps it updated with new information related to case studies, best practices, green remediation news, upcoming events, and reference documents. Most recently, EPA released "Methodology for Understanding and Reducing a Project's Footprint," for public comment (the public comment period closes November 16, 2011). EPA has also hosted a series of three conference calls with the international community to help communicate how green remediation and sustainability is being addressed in other countries.

Various States: At least 8 states are advancing green remediation or GSR through the development of policy and/or guidance documents and tools. For example, California has developed a qualitative tool for comparisons of treatment alternatives called the Green Remediation Evaluation Matrix that can help decision makers identify the greenest alternatives for remediation.

Department of the Navy: The Navy, through its Naval Facilities Engineering Command (NAVFAC), is approaching implementation of GSR through its existing remediation optimization program. NAVFAC has developed a Sustainable Remediation Fact Sheet [7], which suggests that GSR reviews be considered during remedy selection, design, and remedial action optimization phases. In addition, the Navy has a collaborative effort with Battelle and the US Army Corp of Engineers (USACE) to develop a GSR assessment tool called SiteWise™ . A second version of SiteWise has been developed and is available on the Navy's Green and Sustainable Remediation Portal [8].

Department of the Army: The USACE has developed a decision framework for incorporating sustainable practices into Army environmental remediation projects throughout the remediation process. The framework is included in "Decision Framework for Incorporation of Green and Sustainable Remediation Practices into Environmental Remediation Projects" (USACE 5 March 2010, Interim Guidance) [9].

Department of the Air Force: Air Force efforts on GSR are being lead by the Air Force Center for Engineering and the Environment (AFCEE). AFCEE has developed a number of tools to facilitate the quantitative evaluation of sustainability metrics for a variety of remediation technologies. The tool, call Sustainable Remediation Tool (SRT), is available on the AFCEE web site:
(http://www.afcee.af.mil/resources/technologytransfer/programsandinitiatives/sustainableremediation/srt/index.asp).
AFCEE is also including GSR language in its contracts, including its performance-based remediation contracts, and is part of the selection criteria.

ESTCP: ESTCP, which is DoD's environmental technology demonstration and validation program, has one project underway related to GSR. The project entitled "Quantifying Life-Cycle Environmental Footprints of Soil and Groundwater Remedies," seeks to establish a common DoD database and approach for evaluating life-cycle impacts.

ITRC: In November of 2011, the ITRC will publish a technical and regulatory guidance document entitled "Green and Sustainable Remediation." This is the first regulatory consensus document on GSR published in the United States.

ASTM International: ASTM commissioned a workgroup to develop a standard guidance for green and sustainable remediation. ASTM established the workgroup to provide best management practices and guidance for implementing GSR into remediation projects. Since the work group was formed, there were two separate opinions on what the standard should focus on. Some wanted it to only address green remediation while others wanted it to address both green and sustainable remediation. After two years of drafting documents for ballot voting, the group recently came to the conclusion that a single standard would not be accepted by the group as a whole, at this time. Consequently, at the most recent ASTM meeting (November 2011), the work group agreed to split up into two separate work groups with one focusing on green remediation and the other focusing on sustainable remediation. The intent of both groups is to develop standard guidance documents that allow a project that follows the guidance to be claimed as being green or sustainable. Once finalized, it is envisioned that the ability to claim a project as green or sustainable will create greater demand for green or sustainable remediation practices.

Sustainable Remediation Forum (SURF) (US): SURF has been meeting three to four times per year since 2006. Initially, SURF was a group of people representing different remediation industry stakeholders who came together on a regular basis to determine if it was important or necessary, to develop sustainable remediation practices for the remediation industry. In 2010, SURF was established as a non-profit charitable organization with a mission to provide research and education on topics related to sustainable remediation. At the end of 2011, SURF can claim over 200 members representing a range of industry stakeholders, including student chapters. SURF also has a strong technical initiative group that provides case studies, white papers, and technical presentations on sustainable remediation that further the education and training on topics related to sustainable remediation. Additional information about SURF, as well as sustainable remediation resources, can be found at sustainableremediation.org.

SURF UK: SuRF UK is run / organized by CL:AIRE (Contaminated Land: Applications in Real Environments). It is led by a steering group of individuals representing a range of industry stakeholders. SURF UK has developed a framework for implementing sustainable remediation and has identified 18 indicators to be considered in the evaluation of remediation projects. They have also developed a case study template for reporting results. Additional information about SURF UK can be found at:
http://www.claire.co.uk/index.php?option=com_content&view=article&id=182&Itemid=78

IMPLEMENTATION OF GSR PRINCIPALS

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. Development and implementation of 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 at the beginning of a project.

2. Inclusion of green and/or sustainable criteria in the evaluation of alternative remediation technologies and approaches. This involves the 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 pre-selected remediation technology as green as possible
Inherently green remediation technologies may mimic or use natural processes, including:

- 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 and/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.

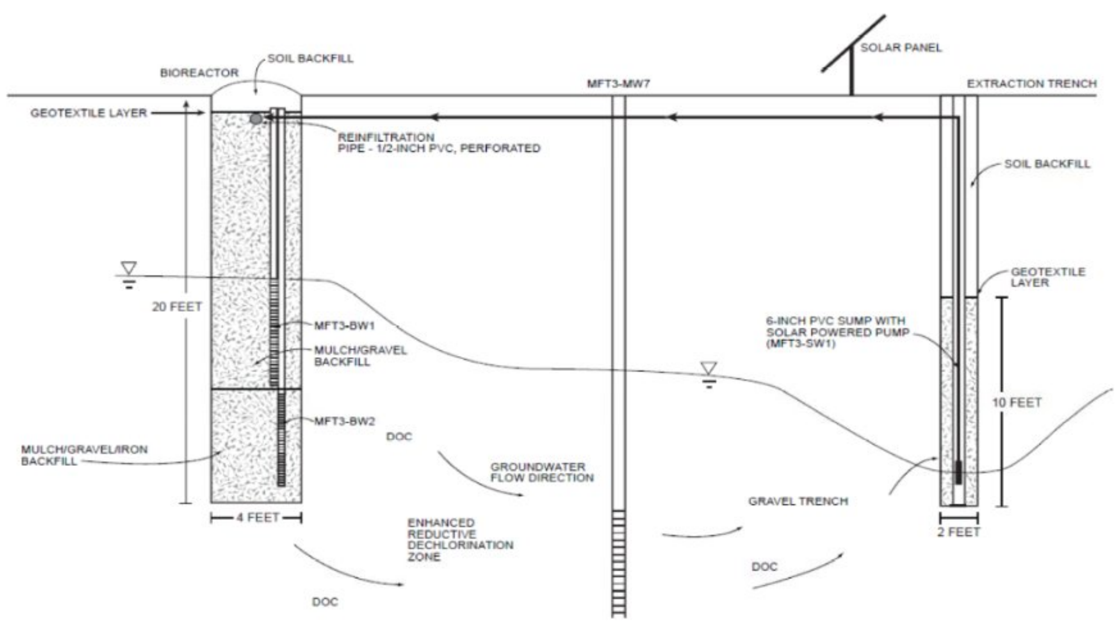

Fig. 2. Passive, Solar Powered Bioreactor

It should be noted that 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 pre-selected remediation technology greener or more sustainable, the following factors are typically addressed.

- Reduction of energy use and increased energy efficiency. Examples of improving energy efficiency include using variable frequency drives on groundwater extraction pumps, and using more energy efficient lighting in remediation buildings.

- Use of renewable energy sources, such as solar or wind for electricity generation and bio-diesel as vehicle fuel.

- Optimized use of equipment. For example, reducing idle times of heavy equipment can reduce emissions.

- Reduction of fresh water consumption and maximized water reuse. For example, using treated water or recycled water for dust control during excavation to reduce fresh water use.

- Maximized recycling, reuse, and reduction of materials including wastes.

- Reduction of impacts on ecosystems and ecological receptors.

- Reduction of negative impact on human use of resources such as land, water and recreation.

Since DOE has a number of very large remediation programs that require large infrastructure systems, there are many opportunities to make these infrastructure systems greener. These can include "office" efforts to reduce paper, optimizing vehicle miles driven around large sites by encouraging use of carpooling, and use of teleconference systems rather than face-to-face meetings. Remote monitoring of wells and other equipment to reduce trips to remote facilities is another example of making the remediation greener.

Another way to greener technology is the use of In Situ Decommissioning (ISD) for highly radioactively contaminated facilities [10]. ISD involves entombment of the facility and may be considered greener since less waste is produced and fewer truck trips are required for disposal, compared to complete demolition and disposal.

EPA has produced a number of fact sheets on Green Remediation Best Management Practice with the objective of providing guidance on how to make pre-selected remedies greener [11]. The fact sheets have been developed for a number of technologies and remediation areas. Examples include Excavation and Surface Restoration, and Integrating Renewable Energy into Site Cleanup. The "Green Remediation: Best Management Practices for Excavation and Surface Restoration" [12] provides a number of practices that can be undertaken to reduce the environmental footprint of soil remediation using excavation. Some of these include using biofuels in the excavation and hauling of 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.

A specific example of making excavation greener, is the application of "super dump trucks" at Hanford for the transportation of excavated soil to Environmental Disposal Facility (ERDF). The new dump trucks haul an average of 24 tons, which is 6 tons more than the 18 ton roll-off boxes which were previously used. Figure 3 is a photo of one such truck. The use of these trucks reduces the number of truck trips. The new trucks also eliminated a stop at the container transfer station for each load since waste is directly loaded onto trucks. Less labor is needed, since roll-off boxes no longer needed to be staged and loaded for transportation and trucks could dump waste directly into the Hanford landfill. Injuries were also reduced with the installation of automating equipment that eliminated the need for personnel handling tarps that were difficult to maneuver.

Fig. 3. Supper Dump Truck

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 2009 US EPA OSWER policy for greener cleanups, the EPA [3] 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

Sustainability evaluation of a set of remedial alternatives can be performed in a number of ways. SURF [13] recommends a tiered approach. The three tiers that could be used are:

- Tier 1: standardized, non-project-specific, qualitative evaluation,
- Tier 2: Project-specific and non-project-specific information and follows a semi-quantitative approach, and
- Tier 3: most detailed, project specific quantitative evaluation.

There are a range of tools that can be utilized to assess the impacts or footprint of a project. A Tier 3 evaluation may be done using footprint or Life Cycle Assessment (LCA) tools. Footprint tools typically look at emissions of selected indicators (e.g., green house gases, nitrogen oxides, sulfur dioxides, particulate matter, energy) that are generated as a result from implementing a remediation project. A more comprehensive evaluation could be accomplished using traditional LCA tools. Frame works for performing LCAs are available from ISO (the International Organization for Standardization), primarily ISO 14040 and ISO 14044. Favara *et al* [14] developed a paper that streamlines the integration of ISO principles for completing footprint evaluations and LCAs for Remediation projects. LCA applications on remediation projects are becoming more frequent because some practioners believe they address more comprehensive environmental impacts, evaluate life cycle issues better, and have greater functionality for interpretation as compared to footprint tools.

Figure 4 below represents the range of environmental impacts that can be evaluated with LCAs. The y-axis represents the emissions from the project in terms of a world population count (i.e., the project's human toxicity represents the equivalent to the human toxicity emissions of a population of approximately 120,000 people):

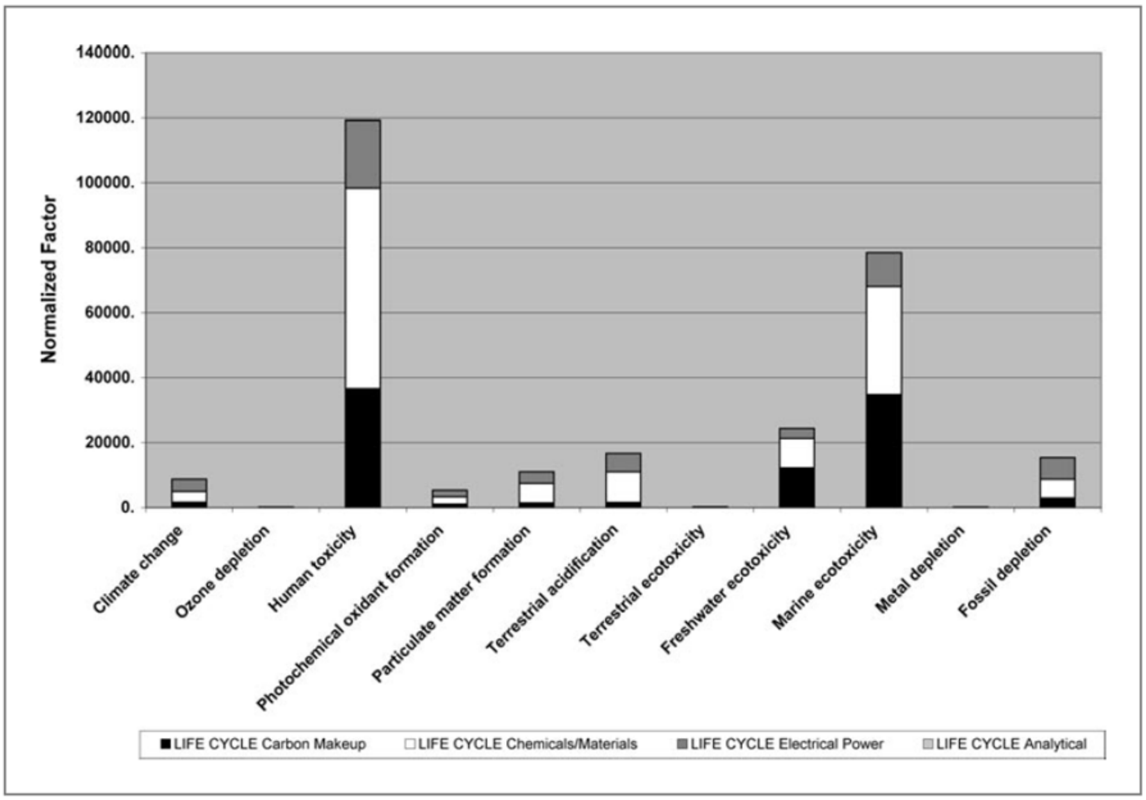

Figure 4. LCA results reporting population equivalents by environmental impact category and project element [14].

LCA's evaluate all the chemical emissions to soil, water, and air and normalize them to an indicator parameter (e.g., carbon dioxide equivalents for climate change potential, sulfur dioxide for acidification). Figure 4 is only a small fraction of the information that can be learned from completing LCA's for remediation projects.

Footprint analyses focus more on discrete emissions, as described above. An example of output from a footprint tool, SiteWise™ is presented in Figure 5 for green house gas equivalents. Similar graphical output is available for the other parameters that SiteWise™ calculates.

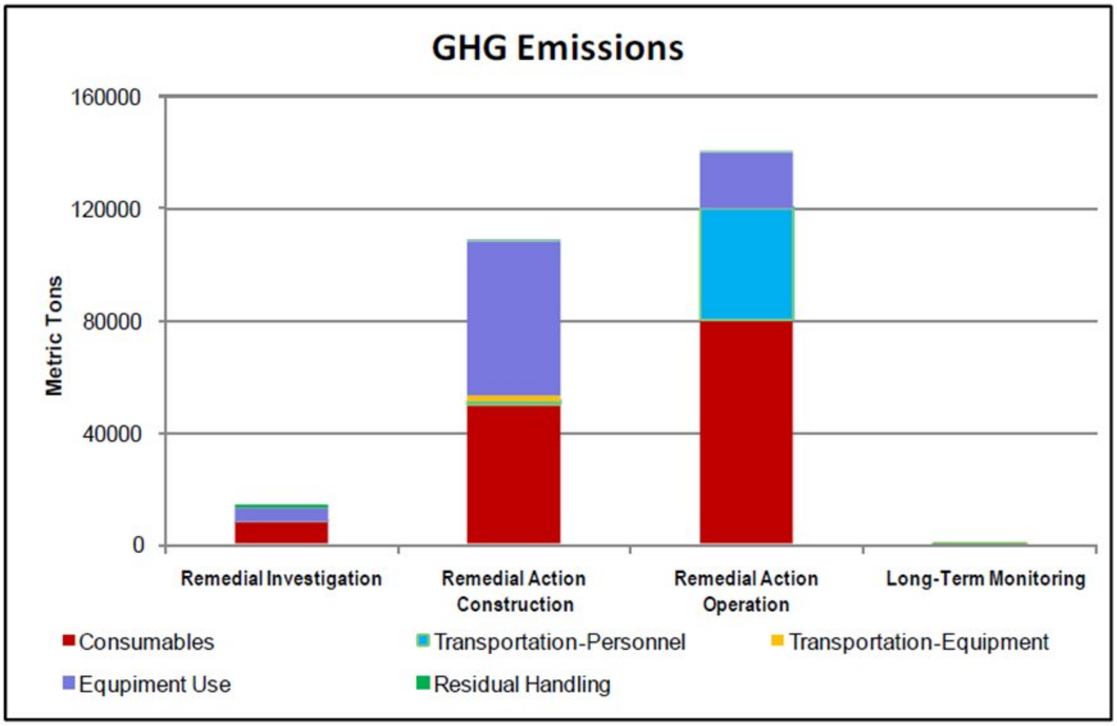

Figure 5. GHG emissions, in metric tons, by project phase. [8]

When it comes to deciding whether to use a LCA tool or a footprint tool, there is no single correct answer. The tool that is selected should be based on the questions that need to be answered.

Incorporating the quantified indicators from footprint or LCA tools into 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 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.

While incorporating the quantitative results from footprint and LCA tools is challenging from a CERCLA perspective, utilization of these tools can still help project teams make more informed decisions and identify opportunities for optimization by reducing the emissions or environmental impacts of remediation projects.

CONCLUSIONS – IMPLICATIONS FOR SOIL AND GROUNDWWATGER REMEDIATION

GSR provides a number of challenges for remediation professionals performing soil and groundwater remediation projects. 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 states. However, this process also provides new opportunities to think differently and look at the bigger picture of the overall benefit we are providing with our remediation projects.

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.

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