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Research article

Utilization of waste materials, non-refined materials, and renewable energy in in situ remediation and their sustainability benefits

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ABSTRACT

In the ramp-up to integrating sustainability into remediation, a key industry focus area has been to reduce the environmental footprint of treatment processes. The typical approach to integrating sustainability into remediation projects has been a top-down approach, which involves developing technology options and then applying sustainability thinking to the technology, after it has been conceptualized. A bottom-up approach allows for systems thinking to be included in remedy selection and could potentially result in new or different technologies being considered. When using a bottom-up approach, there is room to consider the utilization of waste materials, non-refined materials, and renewable energy in remediation technology—all of which generally have a smaller footprint than processed materials and traditional forms of energy. By integrating more systems thinking into remediation projects, practitioners can think beyond the traditional technologies typically used and how technologies are deployed. To compare top-down and bottom-up thinking, a traditional technology that is considered very sustainable—enhanced in situ bioremediation—is compared to a successful, but infrequently deployed technology—subgrade biogeochemical reactors. Life Cycle Assessment is used for the evaluation and shows the footprint of the subgrade biogeochemical reactor to be lower in all seven impact categories evaluated, sometimes to a significant degree.

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1. Introduction

The remediation industry uses a range of physical, chemical, and biological processes to remove, destroy, degrade, and immobilize contaminants. These processes, which represent the range of technologies used in the 30-plus-year history of the remediation industry, were developed and utilized because they were considered cost-effective. During the development and deployment of these technologies, the sustainability of these technologies was not a general consideration. Since 2006, when the concept of sustainable remediation was first seriously considered in the remediation industry, we now have more information to assess the sustainability attributes of these technologies and have a better understanding of what may constitute a sustainable treatment technology. There are a number of definitions for sustainable remediation. One such definition developed by the Sustainable Remediation Forum (SURF) describes it as "the use of sustainable practices during investigation, construction, remediation, redevelopment, and monitoring of environmental cleanup sites, with the objective of balancing economic viability, conservation of natural resources and biodiversity, and the enhancement of the quality of life in the surrounding communities" (SURF, 2016).

The use of waste materials, non-refined materials, and renewable energy offers opportunities to reduce the footprint of remediation applications because they generally have lower environmental footprints, as compared to traditional materials and energy sources, and can often provide a similar remediation benefit. By considering these sustainable components of treatment early in the remedy development phase of work, new and innovative treatment solutions can be developed. However, these sustainable components are often overlooked because the remediation industry typically applies the principles of sustainable remediation after the remedy has been conceptualized or designed. By that time, the opportunity to include sustainability components that can result in innovative and sustainable treatment technologies has passed.

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2. Sustainable remediation implementation approaches

Traditionally, most applications of sustainable remediation use a “top-down” approach. A top-down approach is where the remediation option is developed using traditional industry approaches (i.e., sustainability is not substantively considered in alternative development) and only after it has been developed, will it be evaluated for sustainability. The sustainability analysis may include application of best management practices, footprint analysis, or life cycle assessment (LCA). In this manner, a remediation technology is subjected to conservation analysis (e.g., use less material and energy be used), optimized (getting better results by evaluating different configurations), and minimizing the impacts of the selected technology (e.g., using footprint analysis or LCA to identify impacts that can then be assessed for reduction).

Sustainable remediation offers an opportunity to think differently about remediation technologies when it can underpin broader thinking about the impact of treatment technologies on the environment, society (e.g., the local community), and economics. This is sometimes referred to as “systems thinking” because it evaluates the components that make up the entirety of the treatment technology. For example, rather than recommending a treatment technology, systems thinking would consider environmental, social, and economic impacts and influence how a treatment technology is conceptualized to minimize its the sustainability footprint. Instead of using the top-down approach and then simply improving on the remediation technology, systems thinking is the basis for utilizing more sustainable technology components and project approaches that are built on a sustainability premise. Systems thinking can be thought of as a “bottom-up” approach. This “bottom-up” approach represents the best opportunity for sustainable remediation to be a game changer in how remediation technology is implemented, because it forces thinking about new or infrequently used approaches rather than using traditional approaches. Sustainable thinking also includes the steps of conservation analysis, optimization, and evaluation for minimizing the impacts of the selected technology, but only after sustainability thinking has been integrated into the technology application.

One way to visualize the difference between a “top-down” and “bottom-up” approaches is represented in Fig. 1.

On the bottom-left side of Fig. 1 is a large circle that represents the sustainability footprint (e.g., impacts to society, economics, and environment) of all the traditional technologies used in the remediation industry. Once these technologies have been selected for evaluation or implementation, a top-down approach to include sustainability is employed. It is difficult to maximize sustainability potential with a top down approach because the traditional remediation technologies have not been designed for sustainability. Therefore, it is only possible to apply the concepts of conservation, optimization, and minimization. On the top-right side of Fig. 1 is smaller circle representing the starting point for technologies designed for sustainability and where we consider non-traditional approaches to remediation that may result in new (or underutilized) technologies which have a lower sustainability footprint. We can still, from here, employ the concepts of conservation, optimization, and minimization to further reduce the footprint. This latter approach is a bottom-up approach that uses systems thinking to identify more sustainable technology components and approaches to meet cleanup objectives.

3. Systems thinking and LCA

The National Research Council (2014) recommended the U.S. Environmental Protection Agency (EPA) “use a systems thinking approach for incorporating sustainability concepts and applying the appropriate tools.” One such tool referenced is LCA, which can be used to evaluated negative impacts of remediation technologies. Although LCA has been used for several decades in some industries to provide a better understanding of the life-cycle impacts of products on the environment and human health, LCAs have been sparingly applied in the remediation industry. Morais and Delerue-Matos (2010) identified 12 papers in LCA literature that focused on site remediation. Hou et al. (2014) evaluated the impacts of sediment remediation at the London Olympic Park. Lemming et al. (2012) evaluated four treatment alternatives for the remediation

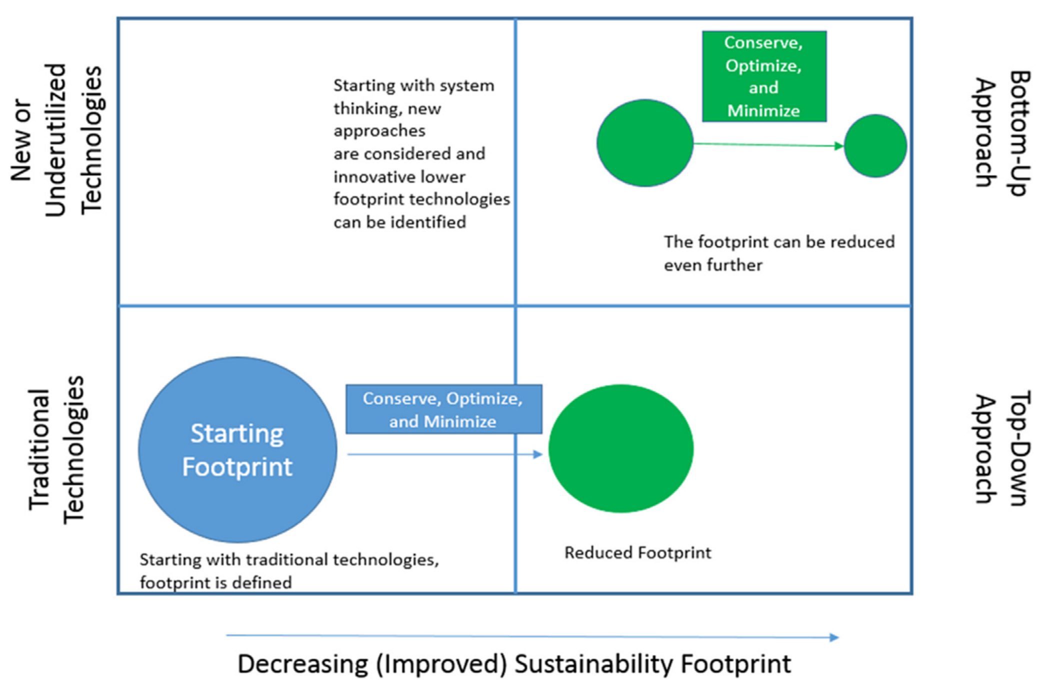

Fig. 1. Visualization of top-down and bottom-up thinking.

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