

Sustainable Remediation Panel— Utilizing Quantitative Evaluation Techniques to Support Sustainable Remediation Projects

Paul J. Favara

Todd M. Krieger

Axel D. Rieke

Daniel J. Watts

Remediation developed a Sustainable Remediation Panel in the Summer 2009 issue, which featured the Sustainable Remediation Forum White Paper. The panel is composed of leaders in the field of sustainable remediation who have volunteered to provide their opinions on difficult subjects related to the topic of how to integrate sustainability principles into the remediation practice. The panel's opinions are provided in a question-and-answer format, whereby selected experts provide an answer to a question. This issue's question is provided below, followed by opinions from four experts in the remediation field.

Life cycle assessment and environmental footprint analysis are considered by many to be important elements of the sustainable remediation evaluation process. At what point in the remediation process are these techniques most useful and why? Are there certain types of projects that are more amenable to these analytical tools? How can the techniques be effectively used to help improve the sustainable aspects of a cleanup project?

PAUL J. FAVARA

At What Point in the Remediation Process Are These Techniques Most Useful and Why?

Life-cycle assessment (LCA) and footprint analysis studies can be incorporated into any step of the remediation process life cycle: site planning and investigation, remedy selection, remediation design and construction, operation and maintenance (O&M), and closure. However, most practitioners apply LCA and footprint analysis in the middle three phases of the remediation project life cycle, and most often in the remedy-selection phase.

The remedy-selection phase of the project offers the opportunity to evaluate the footprint of each alternative. Footprint analysis or LCA can provide information for decision makers to understand the environmental burdens of the alternatives being evaluated. This information can be factored into the other decision criteria used by decision makers for remedy selection.

During the design and construction phase, a baseline footprint for the remedy can be established to raise awareness of the burdens associated with the project. Once these burdens are identified, the project team can evaluate options (e.g., through optimization or value-engineering activities) to reduce the burden. Consider an example where Portland cement is utilized to stabilize contaminated soils. Performing the baseline footprint analysis would reveal high greenhouse gas (GHG) emissions with Portland cement. This could lead the team to evaluate cement that uses slag or fly ash to reduce the GHGs associated with the stabilization phase of work. The use of lower-footprint cement not only reduces the GHG emissions for the project but also provides a reuse opportunity for waste slag from steel manufacturing or fly-ash from power production.

As long as there is value to answering the questions posed by the scope and goal of the study, footprint analysis and LCA are appropriate and valuable techniques to utilize on any project.

The construction phase could evaluate green construction practices to minimize the footprint of the construction phase. This could include evaluating cleaner fuel blends for construction equipment (e.g., biofuel), optimizing transportation modes (e.g., consider rail or barge in lieu of trucks), and use of on-site waste materials as fill (e.g., break up concrete slabs that would otherwise be transported off-site to construction landfills).

The O&M phase of work offers opportunities to utilize footprint analysis and LCA as part of optimization studies. Often, review of remediation projects in the O&M phase reveals system inefficiencies and changes in site conditions that warrant a re-evaluation of the design or remedy. As options are evaluated, footprint analysis and LCA can be used to provide decision makers footprint information for the options to be considered in the decision-making process.

Are There Certain Types of Projects That Are More Amenable to These Analytical Tools?

Footprint analysis and LCA studies are scalable and can be applied to any project. Some efforts may only require a few hours of labor to complete an evaluation (e.g., Case Study No. 2 in “Guidance for Performing Footprint Analyses and Life-Cycle Assessments for the Remediation Industry” in this issue). Others can require significantly greater effort. As described in Step 1 of the guidance in this journal, it is important to define the goal and scope of the study. As long as there is value to answering the questions posed by the scope and goal of the study, footprint analysis and LCA are appropriate and valuable techniques to utilize on any project.

How Can the Techniques Be Effectively Used to Help Improve the Sustainable Aspects of a Cleanup Project?

The end result of a footprint analysis or LCA is a summary of potential impacts and interpretation of the impact results. To some extent, the ability to improve the sustainable aspect of a cleanup project is dependent on the level of detail reported in the footprint analysis or LCA. A footprint analysis typically looks at one to several metrics, so all decisions/opportunities to improve the sustainable aspect of the project will depend on the metrics evaluated and minimizing their respective burdens. As an LCA can look at significantly more metrics, there is additional opportunity to identify options to reduce burdens of a larger number of metrics. Also, with LCA, there is a greater ability to evaluate how changes to a remediation project impact different metrics so practitioners are able to also better consider potential burden shifting (where reduction of one

burden—say, carbon dioxide—can lead to an increase of another burden—say, acidification potential) with different variations of an alternative or comparison between alternatives.

TODD M. KRIEGER

The product of any life-cycle assessment is information. The intention of performing an LCA around a remediation process is to help complete a cleanup in an environmentally sound way without shifting environmental burdens or creating unintended consequences. The earlier an LCA is performed in the remediation process, the broader the impact it may have. Using LCA during remedy selection provides the opportunity to raise all the issues, even those beyond the fence line, and identify trade-offs among the options, particularly since LCA is much better at comparative rather than absolute analysis. Furthermore, greater improvements are more likely achievable among remediation technology alternatives than within a selected remedy. Of course, an LCA is only as good as its input data. Much of the input required for an LCA mimics that required for a cost analysis and, consequently, can be performed concurrently. Inputs, such as the contaminant quantities, reagents, or activated carbon use rates; transport distances; and the electricity requirements, should all be quantified prior to performing an LCA. By performing an LCA, the practitioner will also identify hot spots, or key areas of concern within each remedy. Once a remedy is selected, these hotspots can be further developed by looking at sourcing options and evaluating uncertainties, such as use rates, transport distances, electricity supply, or other factors to identify potential improvements.

As sustainability analyses or LCAs are not trivial exercises and resources including LCA-knowledgeable personnel are limited, not all projects warrant a full evaluation. While most projects, no matter how inexpensive or simple, could benefit from at least a glance through the prism of sustainability, remediation practitioners can ask themselves the following questions before commencing a detailed LCA:

- Do the remedial options result in different end points? (i.e., is the contaminant destroyed in one case but just relocated in another?) Is a different amount of contaminant remediated? Is the land available for redevelopment in one case but not in another? Is one project complete in 2 years while another takes 50 years?
- Do the options differ by more than just energy use (diesel fuel consumption or electricity)—that is, do they use different technologies?

If one can answer “yes” to any of these questions, then a more detailed analysis is likely valuable. Size or cost of a cleanup is not always the best gauge to determine if an LCA is warranted. Small individual projects that are representative of many similar projects, such as a gas station cleanup, may still warrant evaluation as the results could be used over and over again.

As there are not an infinite number of remedial options, the use of life-cycle assessment will become easier over time as more cases are evaluated. Completed studies can be used as templates for future studies with changes made for contaminants and geography. By understanding the burdens associated with remedial activities through the use of LCA, more informed decisions can be made, leading to cleanups with lower environmental impacts without creating future remediation elsewhere.

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AXEL D. RIEKE

While the use of sustainability evaluations, including environmental footprint analysis, are still in their infancy in the remediation industry, life-cycle assessment is a widely practiced technique based on established industry standards, such as the International Organization for Standardization's (ISO) 14000 series, a framework for environmental management systems (EMSs) and product assessments. When evaluating sustainability, LCA can be a powerful tool that provides useful information to assess metrics and related impacts of a remediation project, including the environmental benefits of removing contaminants from the site, and the associated environmental degradation and consumption of natural resources and raw materials.

LCA is a useful quantitative tool to assess metrics and balance environmental impacts and is most useful when applied early and uniformly during remedy selection and design, although it can be incorporated at almost any stage of a project.

Sustainability evaluations can easily incorporate existing standardized LCA components to provide supplemental information during remedy selection, design and construction, and optimization. Two useful analytical techniques are Life Cycle Inventory Analysis (LCI) and Life Cycle Impact Assessment (LCIA). As in product assessment, LCI can quantify raw materials and waste streams, and energy consumption of various remedial alternatives and LCIA can quantify their respective impacts on the environment, resulting in an "environmental balance sheet" that facilitates a comparison of cleanup options. Remedies involving high volumes of continuous material flow (e.g., a granular activated carbon [GAC] groundwater treatment system) are particularly amenable to LCI during the remedial design stage, but can also be quite useful during materials acquisition, construction, and optimization. At the remedy-selection stage, energy-sensitive operations (e.g., *in situ* thermal remediation) are more amenable to LCIA, which can help determine if environmental impacts are being shifted from one medium to another (e.g., transference of pollution from local soil and groundwater to the regional or global atmosphere). While a more limited environmental footprint analysis may focus on carbon dioxide emissions and water consumption, LCIA has the ability to offer a broader base for decision making, including depletion of abiotic resources, land use, stratospheric ozone depletion, human toxicity, eco-toxicity, photo-oxidant formation, acidification, and nitrification, as well as climate change.

LCA is a useful quantitative tool to assess metrics and balance environmental impacts and is most useful when applied early and uniformly during remedy selection and design, although it can be incorporated at almost any stage of a project. If sustainable remediation practitioners are looking for a robust and more holistic evaluation of the impacts of their projects, LCA provides a standardized tool that is objective and comprehensive, and can greatly improve the transparency of the remedial decision-making process.

DANIEL J. WATTS

Environmental life-cycle assessment is a powerful tool for evaluation of the sustainability characteristics of a process, product, or large-scale operation. Environmental footprint analysis can provide a more focused sustainability characterization typically where a single type of impact factor, such as energy use, is deemed to be of overriding importance. When applied to evaluation of remediation projects to encourage use of more sustainable approaches, the two tools are most frequently used late in the planning process. Using the tools at this point allows selection of the most sustainable approach from among a

relatively small number of remedial approaches, or allows improvement in the overall sustainability of a project by encouraging changes within the operating details of the remediation after the most unsustainable components have been identified. These changes may include, for example, changes in materials of construction to those having less impact on overall life-cycle energy use or inclusion of electricity produced from renewable sources.

Such late-in-the-project uses of the LCA and footprint tools have a history of contributing to more sustainable remediation projects. As more projects reach completion with use of these tools, the level of experience will rise, the available data about sustainable remediation will increase, and practitioners will become more familiar with these approaches. While all of that will certainly raise the level of sustainability, it should also pave the way for broader application of LCA and footprint analysis by moving their use to earlier in the process by considering alternatives to land use following remediation. In LCA terms, this might be called widening the boundaries of the assessment problem. Thinking of a remediation not simply as a removal of contaminants, but as an opportunity for careful planning for beneficial use of the land involved can provide additional avenues for LCA and related analysis approaches to facilitate enhanced sustainability. Even though a broad range of land uses is possible, extending, for example, from nature preserves, parks, and housing to industrial sites, a broader LCA application can help identify different combinations of remediation technologies, materials, time frames, and energy uses that could yield more sustainable results.

It is also true that such a broadening of the problem would likely result in technical complications at present. Appropriate models for future scenarios are not robust or do not exist. Data sets necessary for LCA are not compiled or are incomplete. The increased levels of complexity likely would mean that a longer time would be required for the LCA activity. The similarity of this broader approach with some aspects of Brownfields remediation allow some useful analogies with the preparedness of the industry to take this step, as commented on by Pediditi et al. (2006). Following a survey of monitoring of the long-term sustainability of Brownfields remediation projects by 987 developers in the United Kingdom, of whom about 10 percent responded, the authors reported that there was no tool used that would evaluate holistically the sustainability of possible remediation and reclamation schemes.

On the other hand, in a somewhat related situation, as reported by Lundie et al. (2004), the Sydney, Australia water and wastewater systems successfully have used LCA together with a series of models of future scenarios to do a prospective study to identify the more sustainable options for future development and growth of the combined water systems in that city. This type of work suggests that, with growth of implementation of sustainable remediation, the ability to move the use of LCA and footprint analyses to earlier in the process is possible, and that such movement has the potential to increase the sustainability impact of the entire process.

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Paul J. Favara, P.E., is a technology fellow with CH2M HILL, where he leads the global sustainable remediation practice and technology strategy and deployment initiatives. Mr. Favara is currently serving as president of the Sustainable Remediation Forum. He received his BS in business-oriented chemistry from Western Michigan University and an MS in environmental engineering from the Illinois Institute of Technology. He is a registered engineer in Florida.

Todd M. Krieger, P.E., LCACP, is a DuPont consultant specializing in technical, economic, and environmental evaluations as a member of DuPont Engineering Research & Technology. Mr. Krieger is a Life Cycle Assessment Certified Professional and a board member of the American Center for Life Cycle Assessment (ACLCA). He received his BS in chemical engineering from the University of Delaware and is a registered engineer in Delaware.

Axel D. Rieke is a senior civil engineer with Northgate Environmental Management in Oakland, California.

Daniel J. Watts, PhD, retired as Panasonic Professor of Sustainability at the New Jersey Institute of Technology in Newark, New Jersey. He currently is serving as a research professor at the Institute. His research interests include application of sustainability principles to industrial activities and emerging contaminants in water. Dr. Watts received his BS in chemistry and botany from The Ohio State University and his AM and PhD in botany and organic chemistry, respectively, from Indiana University.
