Sustainability Index for Comparison of Environmental Remediation Technologies-17492

Sarah Bird*, Alexis Smoot*
*DOE Fellows, Florida International University
Alexandra Kramer**
**DOE Scholars, University of Maryland

ABSTRACT

Site remediation is a multi-decade process that incorporations planning from a variety of parties including stakeholders, regulators, scientists and engineers, and community members. When Best Management Practices are integrated during remediation action at sites, there are significant improvements to a variety of metrics including economic, environmental, and societal factors. Green and sustainable remediation tools are Best Management Practices that are a valuable means to reduce or remove environmental footprints after remedial action at sites. Applying the analysis to future feasibility studies, EM takes the next steps towards being a leader in global sustainability.

The sustainability index is a quantitative test in response to a recent study published by scientists at the Hanford Site detailing an exit strategy for pump and treat remediation technologies in an effort to move away from active remediation in favor of passive techniques. The sustainability index attempts to quantify the relative sustainability of active and passive remediation strategies by examining a variety of metrics and perspectives from those involved in the decision-making process.

Analysis compared 10 metrics encompassing environmental, social, and economic aspects of sustainability for the two types of remediation techniques. Perspectives and values of the stakeholders, regulators, scientists and engineers, and community members involved the decision-making process were also incorporated in this tool. Data were evaluated from active and passive remediation technologies at two locations (Richland, Washington and Mound, Ohio). Data suggest passive remediation technologies performed better in terms of sustainability performance than active technologies.

Switching from active remediation to passive remediation techniques has the following impacts: aids in the conservation of local ecosystems, reduces community impacts and improves the community perception of the cleanup, lowers the life-cycle cost of the project, and contributes positively to global sustainability by using less energy and raw materials.

INTRODUCTION

The US Environmental Protection Agency (EPA) defines green remediation as that which not only takes into account all of the environmental effects of the remedy implementation, but also utilizes available options to reduce or remove the environmental footprints of cleanup actions. Essentially, it is the integration of best management practices (BMPs) that may be employed during a project, especially considering sustainability aspects including emerging techniques offer significant environmental and social benefits while still being economical. As environmental remediation is the main purpose of the Department of Energy's Office of Environmental Management (DOE EM), it aligns with the goals of the DOE Sustainability Performance Office (SPO) to consider this method before defaulting to using the cheapest or fastest remedies (1).

Pump-and-Treat (P&T) remediation is an established technology which is currently in use at numerous DOE sites across the country. The technology has three main characteristics: groundwater extraction, aboveground treatment, and groundwater monitoring. It is an active treatment method, which means it is human-run and quite energy and water intensive. Some benefits of using this treatment system include effective plume and source containment and reduction, strong aboveground operational performance, and ease of integration and co-performance with other technology elements of a remedy. Some negative impacts include difficult secondary waste handling and disposal, high energy and operational costs, poor sustainability performance, and injection well fouling. This remediation technique reflects many of its negative impacts in our chosen metrics: it is generally high life cycle cost, long life cycle, decreasing efficiency over time, and ignores many environmental factors. Primarily because of the many cons of using P&T remediation, it is important to explore other options when examining the best type of remediation for a site (2). Pump and Treat is used as the primary example for active remediation in the intial sustainability index study.

Enhanced Attenuation (EA) and Natural Monitored Attenuation (NMA) are both passive remediation methods, meaning they utilize the natural flows and require little human input after their initial setup. Structured geochemical zones are an example of EA, created by the injection of vegetable oil (and electron donor) into the groundwater to deplete volatile organic compounds (VOCs). These passive remediation methods are beneficial for minimizing the rebound of groundwater concentrations above regulatory targets and avoiding plume expansion in the absence of P&T (2). These positive attributes contrast with the negative metric scores of the active remediation strategies by benefiting environmental factors with a lower life cycle cost.

A 2016 study published by Massachusetts Institute of Technology (MIT) in collaboration with the Boston Consulting Group (BGC) reports that sustainability matters to investors. The article states that three-quarters of executives in investment firms consider good sustainability performance as materially important when making investment decisions. It goes on to elaborate about the growing importance of environmental sustainability for staying competitive in the current market. As investors and stakeholders play a key role in the decision-making process for DOE national labs, this study reveals that sustainability may be best case scenario for all parties involved (Unruh et al., 2016). The index described in this report aims to speak in both qualitative and quantitative terms to provide the data needed to show investors and others involved in decision making how to make more responsible, sustainable choices when it comes to cleanup.

RESEARCH DESCRIPTION

A five step method was used to generate a quantitative value for the relative sustainability of two remediation methods.

(1) Select and define the metrics.

(2) Create bins to normalize the data.

(3) Establish a weighting system.

(4) Design an algorithm to apply the weights.

(5) Compile the data together in a final table to analyze results.

(1) Defining the Metrics

There is no consensus on universal parameters and metrics to describe sustainability. Parameters and metrics were selected based on the triple bottom line (the three pillars of sustainability – economic, environmental and social factors) and relevance to EM's sustainability goals. A total of 10 parameters were selected. Metrics were selected and defined as to the remediation process and their environmental significance was noted (Table 1).

(2) Creating the bins

The second step was creating bins, or ranges of values, for which each metric could be assigned values on a scale of one to five - 1 being the worst, or least sustainable, and 5 was the best, or most sustainable. Putting all of the metrics on the same grading scale allowed us to normalize the data and generate realistic quantitative scores.

Another advantage to using the bins was that the exact data was not needed, which made it easier to gather information and input information for the spreadsheet to see the overall strengths and weaknesses of each specific remediation process.

Table 1: Metrics, definitions, units, and bins assigned to each.

Metric	Definition	Units	Bins
1. Life Cycle Cost (LCC)	Life cycle cost (LCC) – total cost of the remediation process	Dollars ($)	1. 1 billion+ 2. 100 mil – 1 billion 3. 10 mil – 100 million 4. 1 mil – 10 million 5. 0 – 1 million

2. Time	Start of remediation to NMA	Years	1. 100 + 2. 51-100 3. 26-50 4. 6-25 5. 0-5
3. Materials	Percent of land and materials reused and recycled	Percent recycled (%)	1. 0-20% 2. 20-40% 3. 40-60% 4. 60-80% 5. 80-100%
4. GHG emissions (normalized to equivalents of CO_2 using GWP factors)	Greenhouse gas emissions in **metric tons** of CO2, CH4, and NOx	Metric tons	1. 8,000+ 2. 6,000-8,000 3. 4,000-6,000 4. 2,000-4,000 5. 0-2,000
5. Percent of **clean energy** used	Percent of renewable and sustainable energy being utilized (amount of energy from renewable and sustainable sources divided by the total amount of energy used)	Percent (%)	1. 0-20% 2. 20-40% 3. 40-60% 4. 60-80% 5. 80-100%
6. Volume of freshwater used	**Volume** of freshwater used for remediation in gallons	Gallons	1. 100,000 + 2. 75,000-100,000 3. 50,000-75,000 4. 25,000-50,000 5. 0-25,000
7. Source removal - time to ARARS compliance	Time to endpoint of remediation, measured by year until ARARS compliance	Years	1. 100+ 2. 60-100 3. 30-60 4. 10-30 5. 0-10
8. Environmental services	<u>Disposal</u> – acts as an absorptive sink for residuals (i.e. carbon sequestration); Change in pH as a result of remediation <u>Economic</u> functions such as lumber and pharmaceuticals (biodiversity and	+ or -	1. Net negative 2. Medium-negative 3. Neutral 4. Medium-positive 5. Net positive

	ecosystem health are important factors); property value <u>Recreational</u> services for human beings such as public parks and natural areas		
9. Community impact	If/ how the community is affected by the cleanup & how people see the remediation as impacting them (i.e. turning the river green)	+ or -	1. Negative perception 2. Somewhat negative 3. Neutral 4. Somewhat positive 5. Positive perception
10. Risk – fatality	Risk of fatality – number of deaths	Number of fatalities	1. 4 + 2. 3 3. 2 4. 1 5. 0

(3) The Weighting System

A survey was designed in order to collect information about which metrics different groups of people involved in the remediation process value as most and least important. When deciding which type of remediation to implement, four categories of contributors in the decision-making process were identified. The four categories we looked at were:

1. Investors or stakeholders
2. Regulators
3. DOE scientists and engineers
4. Community members

We had them fill out a survey ranking the metrics from 1 to 10, with 1 being the most important metrics and 10 being the least important to them based on the professional and personal values.

At the bottom of the survey is an either/ or section that specifically looked at some opposing factors in order for us to understand further what people value.

We received survey results by sending out emails, making phone calls, having face-to-face meetings, and interviewing community members on the Washington mall.

Appendix A shows the document that was used to collect the survey data for the weighting factors in this analysis, which also collected more detailed information about some specific comparisons for further analysis. This data has not yet been applied to the index.

(4) The Algorithm

On one side of the scale is the 1 to 10 ranking system used in the weighting survey (Table 3). Recall that 1 is ranked the most important and 10 is the least important. On the other side is the weighting value each rank was assigned.

In the weighted score, the bin score is multiplied by a percentage based on its rank to either increase or decrease its relative value based on its importance to each group of people.

For example, the bin score of the highest ranked metric gets multiplied by .19 or 19% weight since it is the most important, compared to the metric with the lowest rank which gets multiplied by just .01 or 1% since it is the least important.

Table 2: Weighting factors used for each rank

Rank	Weight
1	19%
2	18%
3	17%
4	16%
5	15%
6	5%
7	4%
8	3%
9	2%
10	1%

(5) The Index

All of the steps were combined into a table in an Excel spreadsheet to generate a template for the actual index (Figure 1). On the spreadsheet, the 10 metrics were listed down the middle so that two remediation techniques could be compared side by side. The inner columns are for the raw bin values or estimations obtained from the site being examined for each process. The outer columns will then calculate the weighted values depending on the ranking given to each metric by the group being examined.

At the bottom of the table (rows 14, 15, and 16), the bin scores are added up to create a raw score in the inner columns, which is divided by the total possible score of 50. In the outer columns the weighted scores are added up and then divided by the total possible of five to obtain a decimal, which is subsequently multiplied by 100 to create a percentage.

Similar to a report card, the percentage from the raw score determines how sustainable the remediation strategy is (with 100% being the most sustainable scenario possible). The value of the weighted score shows whether the sustainability score correlates favorably or unfavorably with the weighted values of particular group being examined.

A1	B	C	D	E	F
2	=C*%	(Bin 1-5)		(Bin 1-5)	=E*%
3	Weighted P&T	P&T	Metric	Oil Injection	Weighted Oil Injection
4			Life Cycle Cost		
5			Time		
6			Recycling/ Reuse		
7			GHG Emissions		
8			Renewable Energy		
9			Freshwater Consumption		
10			Contaminant Removal		
11			Ecological Conservation		
12			Community Impact		
13			Safety/ Risk		
14	=sum(B4:B13)	=sum(C4:C13)	TOTAL	=sum(E4:E13)	=sum(F4:F13)
15	=B14/5	=C14/50		=E14/50	=F14/5
	=B15%	=C15%		=E15%	**=F15%**

Figure 1: The sustainability index template

In order to generate examples of how the Sustainability Index could be practically put to use, data was obtained for two different sites. The first site was Mound, Ohio, which was originally treated using P&T and then transitioned to the Oil Injection/ Funnel and Gate passive remediation method. It has since been cleared to normal standards and is in the process of being re-integrated into the community.

4. RESULTS AND ANALYSIS

Surveys

The results from the ranking surveys distributed to the various group highlighted the values of those involved in the decision-making hierarchy when choosing a remediation method. It was found that typically the values of the regulators and investors were somewhat in alignment, although this system is fairly objective and could vary depending on the regulator and the investor asked. The community members involved in this data had no experience with the cleanup process, and the ranking obtained was, again, very objective and somewhat varied. The most typical responses were used for the purposes of the weighting.

Metric	EPA Regulator	SRS Scientist	Community Members	Investor
Cost	3	2	10	1
Time	2	10	9	5
Recycling	10	9	5	10
GHG Emissions	4	6	4	7
Clean Energy	7	8	3	8
Freshwater	8	7	1	9
Contaminant	1	3	7	3
Conservation	6	1	6	6
Community	5	5	8	4
Risk	9	4	2	2

Table 4: Ranking survey results

Ohio Mound Site Data

The data from the Mound, Ohio site compared the P&T (active) method with an oil injection (passive) system, both of which were used at the site while it was considered active. The raw data obtained for the bins had some surprising similarities, notably the low scores in contaminant removal and clean energy use, as well as the high bin scores for freshwater consumption and risk for both methods. Based on

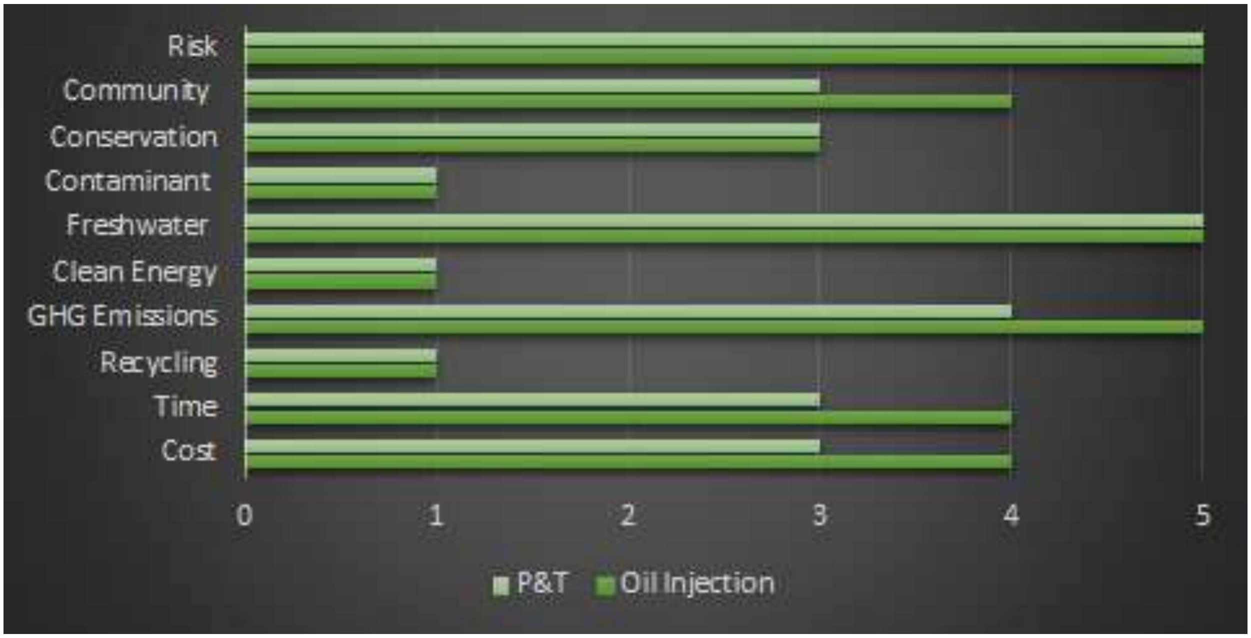

Figure 4: Raw bin data from the Ohio Mound site

The scores for each of the perspectives of the regulators, investors, scientists, and community members can all be found in Appendix B. It can be noted that the oil injection consistently scored significantly higher in terms of sustainability performance when weighted with the values of all four groups.

With further analysis of the charts, one can compare the bin scores with the values and determine why certain score are low while others come out much higher.

5. CONCLUSION

Passive remediation techniques scored much better than active techniques in terms of sustainability performance using the ten parameters that measured the three pillars. Therefore, it can be concluded that switching over to passive remediation techniques from active ones will increase the economic, environmental, and social sustainability of the system. Positive impacts of a more sustainable system include reduction of impact on communities by the cleanup, conservation of local ecosystems and preservation of ecological services, lower life cycle costs, and lower emissions and freshwater use. Switching from P&T to more passive remediation methods also aligns with EM's goals of reducing its carbon footprint by lowering its energy intensity as well decreasing water use intensity.

The sustainability index spreadsheet could be edited to be applied to any two systems to compare their relative sustainability and generate a numerical score. Estimations of the bin data for each metric are all that would be needed to calculate this number. Additionally, the survey could be given to any person involved in the decision-making process to help understand his or her values and weight the raw data in the index accordingly.

Moving forward, the index could be improved by optimizing the bin ranges for each metric based on actual data and statistical averages obtained from other sites which have previously switched from active to passive remediation methods. If the maximum, minimum, and median data points could be obtained for each metric, the bin values could be defined using this data, rather than approximations which are currently in use. This would greatly improve the validity of the data generated using the bins, and improved bin values would increase the accuracy of the final value obtained for the sustainability score.

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APPENDIX A. Weighing Factors Survey

Company/ position (optional):

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Are you a:

Stakeholder/ Investor	Regulator	Scientist/ Engineer	Community Member

Survey:

Rank in order of importance from 1 to 10, where 1 is the most important and 10 is the least important factor when considering type of remediation to implement.

____Total life-cycle cost

____Time

____Recycling (e.g. metals, land, water)

____Greenhouse gas emissions (CO_2, CH_4, and NOx)

____Renewable energy (e.g. solar, wind, geothermal, etc.)

____Freshwater consumption (e.g. groundwater and surface water)

____Contaminant removal

____Local ecosystem conservation

____Worker safety

____Community impact (e.g. recreational spaces, local economy, etc.)

Which is more important to you?

Time	or	Greenhouse gas emissions
Local ecosystem conservation	or	Total cost
Contaminant removal	or	Freshwater consumption
Community perception	or	Local ecosystem conservation
Clean energy	or	Recycled materials
Familiar, established technology (e.g. air stripping)	or	Emerging technology with high potential (e.g. new biochemical methods)
Proven technique, but expensive (e.g. pump and treat)	or	Viable technique, but somewhat unproven (e.g. bioslurping)

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