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ADVOCATE bulletin

CL:AIRE's ADVOCATE bulletins describe practical aspects of research which have direct application to the characterisation, monitoring or remediation of contaminated soil or groundwater. This bulletin reviews two technology sustainability appraisal tools.

Balancing the Pillars of Technology Sustainability in Soil and Groundwater Remediation

1. Introduction

The concept of sustainability is becoming ever more important in the execution of soil and groundwater remediation activities. "Sustainability" when applied in this area, involves the balancing and consideration of factors beyond the primary objectives of managing, containing and/or removing contamination from the subsurface. The concept of *sustainability* or *sustainable development* is derived from the United Nations World Commission on Environment and Development (UNWCED), report titled "Our Common future" and refers to meeting the needs of the present generation without inhibiting future generations from doing the same (UNWCED, 1987).

The intergenerational time dimension is central to the concept, requiring that the burdens associated with a course of action do not extend into the future. Mitigating present and future toxicological risks meets this requirement but may also bring about a shift in impacts from one media to another. For example, removing subsurface contamination at the expense of releasing air emissions due to fossil fuel consumption. Sustainable remediation therefore aims to avoid "trans-medial problem shifting" (Geldermann and Rentz, 2005) by balancing three impact categories, referred to as "the pillars of sustainability" (Figure 1): environmental, social and economic (SuRF-UK, 2010).

A distinction is made between two global approaches to the consideration of secondary impacts. The United States Environmental Protection Agency (USEPA) defines *Green Remediation* as protecting human health and the environment while ensuring that the environmental burden of the clean-up activities is kept to an absolute minimum (USEPA, 2009). The focus, therefore, is on local environmental restoration with the least harm to the global environment. The other approach is that of *Sustainable Remediation* as defined by SuRF-UK, in which the chosen course of remedial action should bring about a net benefit in terms of the environmental, economic and social impacts.

Various technology sustainability appraisal tools exist that allow remediation experts to identify the most appropriate course of remedial action out of feasible alternatives. The existing appraisal tools tend to focus most on environmental impacts and there is a need to further develop these approaches so that social impacts and indirect economic costs can also be accounted for.

The work here reviews two sustainability appraisal tools, REC and SRT in terms of: 1) how each balances the three pillars of sustainability; and 2) to which degree large variation in remediation times are accounted for. The review points out certain key considerations that tool users need to be aware of in performing sustainability appraisals of remediation technologies.

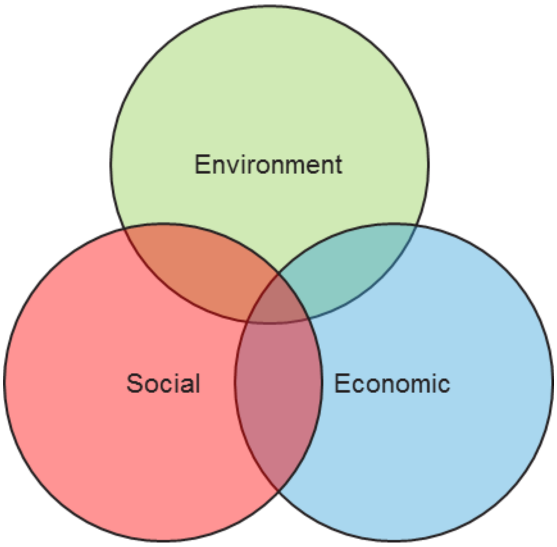

Figure 1: Pillars of sustainability

2. Technology Sustainability Appraisal Tools

2.1 REC

Risk Reduction, Environmental Merit and Cost (REC) is a Microsoft Excel based tool developed in 1995 by a consortium of academic and industry partners and combines the assessment of three impact areas: risk reduction, environmental merit and financial cost (available at www.ivm.vu.nl) (Beinat *et al*., 1997). The risk reduction module evaluates the reduction in risk to human beings, ecosystems and culturally or historically valuable objects brought about by the choice of remedial action. The environmental merit module is based on life-cycle assessment (LCA) and evaluates changes to the environment brought about by the different remediation options within a 30 year time horizon. This includes air emissions, water consumption, fossil fuel consumption and changes to other media, such as surface waters. The cost module allows all costs associated with the different remediation alternatives to be tracked (Beinat *et al*., 1997).

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2.2 SRT™

Sustainable Remediation Tool (SRT) is also a Microsoft Excel based tool developed in 2010 by the United States Air Force (available at www.afcec.af.mil) (US Air Force Center for Engineering, Environment, 2010). SRT can predict emissions and financial costs of different alternatives requiring only a few basic inputs such as volume of soil and groundwater to be treated, contaminant concentrations, contaminant mass and geo-physical and hydrological subsurface characteristics. Risk to workers is calculated in terms of potential on-site injury and is based on man hours required by the alternative. Emissions are calculated according to a life-cycle based approach. CO_2 emissions are valued in terms of US dollars and added to the overall financial cost of the alternative. Changes in surface land-use and changes in groundwater quality are also economically valued in US dollars (US Air Force Center for Engineering, Environment, 2010).

3. Comparison of Tools

3.1 Pillars of Sustainability

Environmental

REC and SRT account for the energy usage and the associated air emissions in detail and this makes up the largest part of the assessment in both tools. The remaining environmental aspect indicators in REC include soil and groundwater quality. SRT predicts the eventual remediation outcome which, depending on the technology, is either total removal of the source zone or limiting plume migration. REC accounts for land consumed on-site during operations and SRT accounts for the post-remediation site land-use. REC considers the space on-site as a resource, like groundwater or fossil fuels. The technology that makes the most efficient use of this resource will perform better for this particular indicator. REC does not however account for space off-site consumed in the treatment of excavated soil (Beames *et al.*, 2014), which is equally relevant to evaluating the spatial efficiency of the technology. SRT on the other hand attributes economic value to the surface space in terms of market value increases and in terms of ecosystems valuation of biodiversity restoration.

Social

The social aspect in REC is entirely based on on-site risk posed by the contamination and how much the toxicological risk can be reduced between alternatives. SRT does not account for varying degrees of toxicological risk amongst alternatives but does account for potential injury to workers. Neither tool includes indicators of hindrance to the local community, during remediation operations or the benefits to the local community of having the site remediated. SRT includes an optional step of allowing for stakeholders and community members to evaluate the results from the tool and determine the weighting schedule (Figure 2); however this is limited to CO_2 emissions, energy consumed, financial cost and ecosystem service value changes.

Economic

The main economic aspect in both tools is financial cost incurred by the stakeholder(s) paying for the remediation. The financial cost calculations in REC are detailed but don't represent the broader economic implications of the different alternatives such as changes in site market value. SRT considers both the total financial costs of remediation operations and the market value of land-use changes; however this is equal across alternatives since it is based on a fixed remediation target for all alternatives. Beames *et al.* (2014) include a detailed overview of the indicators included in REC and SRT and two other tools and compare the tools to what is prescribed by SuRF-UK (SuRF-UK, 2011).

The final result in REC is a standardised graph of the three module results. Unlike REC, SRT aggregates the impact results into a US dollar value and therefore all three pillars of sustainability are represented in a final single score.

3.2 Temporal Aspect of Impacts

The temporal dimension is a parameter in calculating impacts in both of the tools. REC compares changes in contaminant risk and changes in soil and groundwater quality between alternatives, 30 years after remediation operations commence. The time value is fixed at 30 years and does not reflect any significant differences between alternatives that may occur within the 30 year time horizon. For example, one remediation alternative may reduce the contamination to the target level within a couple of months and another within a few years. By year 30, there may be no difference in soil and groundwater quality or contaminant risk due to the additional natural attenuation that would have occurred with both alternatives. The benefit of achieving a certain soil and groundwater quality sooner is therefore not represented. REC does, however include an indicator that evaluates the surface occupied on-site by the different remediation alternatives and is calculated by multiplying space consumed by duration of operations. Neither tool accounts for climate change adaptation.

REC discounts the total financial cost of each alternative and this represents the benefit to the problem owner of postponing the financial cost of the remediation to a future date (Beinat et al., 2007). SRT also allows for a net present value calculation of energy costs and CO_2 emissions dollar equivalents. Discounting energy costs makes sense from a financial perspective especially since it is usually a large part of the total financial cost and it is part of the life-cycle costing approach (Fuller and Petersen, 1996).

4. Discussion and Conclusion

4.1 Balancing the Pillars

REC and SRT both consider the environmental impact aspect in detail, accounting for both the benefits of removing subsurface contamination and the secondary impacts of resources consumed and emissions produced. The detail in the environmental aspect allows it to be the most widely evaluated aspect (Beames *et al.*, 2014). The financial costs of alternatives are also calculated based on a wide range of variables. What does not exist in the tools is a detailed range of potential social implications and secondary economic impacts of different remediation alternatives. Indicators for measuring such impacts have been proposed by SuRF-UK although at this stage they would have to be based on qualitative measurements performed by the tool user (SuRF-UK, 2011). Such indicators could easily be integrated into both REC and SRT. SRT's roundtable evaluation could even allow the possibility of different stakeholders to determine the score and weighting of such social and broader economic impacts.

4.2 Space and Time

Future impacts are reflected in the tools with the following indicators:

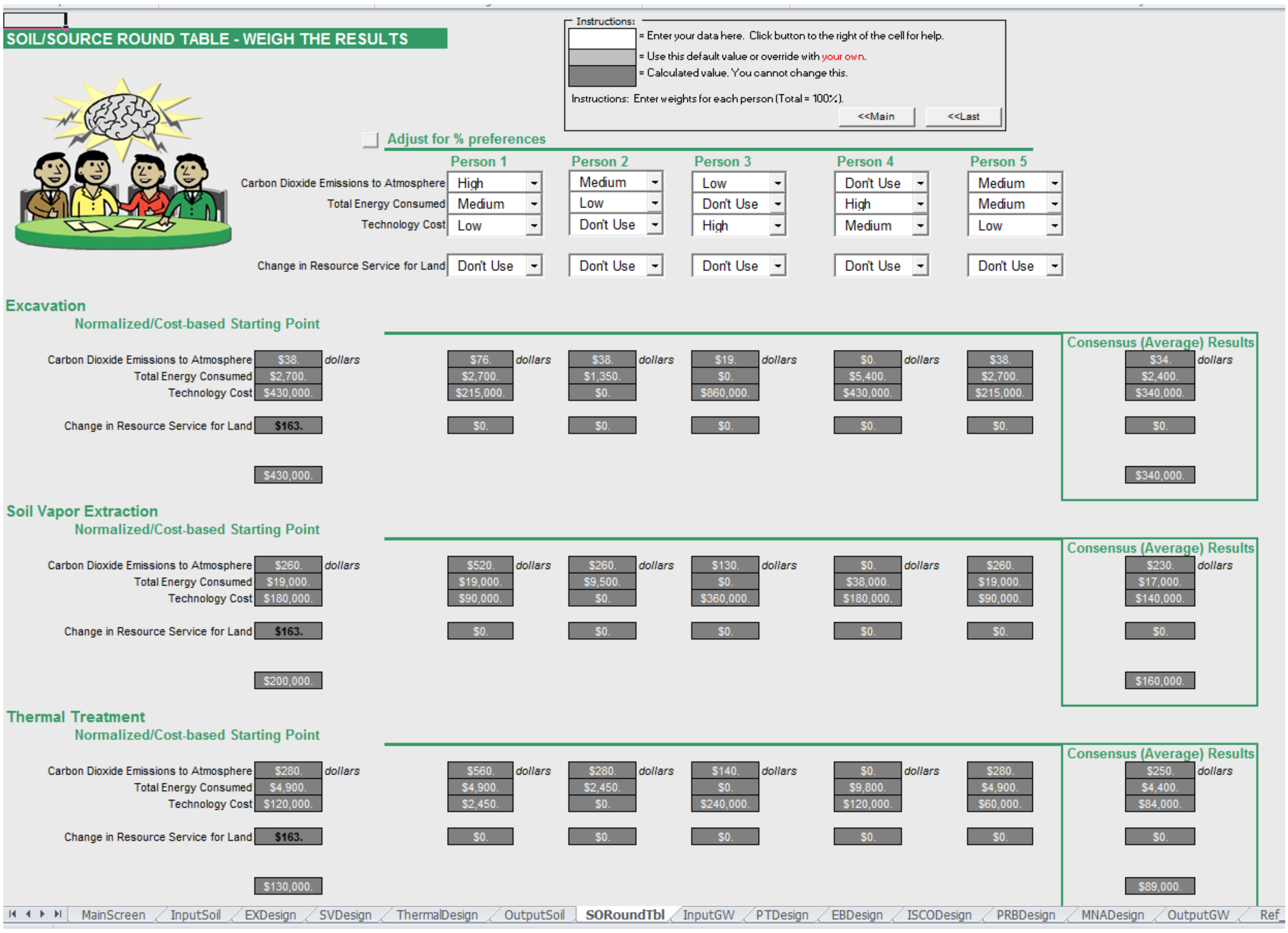

Figure 2: SRT round table weighting

- CO_2 emissions as this is relevant to potential short and long-term changes in the global climate
- Resource depletion, since the future supply of fossil fuels, clean water, fertile soil and arable land are dependent on how quickly these resources are depleted
- Ecosystem preservation which is relevant to the existence of biodiversity in the short and long-term
- Financial costs incurred in the future by the problem owner

There is a direct correlation between using aggressive remediation approaches and higher CO_2 emissions and energy consumption. Aggressive approaches remove the contamination faster but require more resource inputs. Gentler approaches require fewer inputs and therefore tend to be cheaper. Remediation approaches that require more time can also be discounted. A counter balance to this is the benefit of reintroducing the site from idle space to productive space sooner. Particularly relevant to urban sites where land-use is restricted by contamination risk, is the value of surface space as a resource. This would have direct positive consequences for the neighbouring area in terms of land value and the well-being of the local community. The indirect benefit of making use of the already developed space of the site could also prevent space off-site being consumed. An optimal solution may involve a passive approach to treating the contaminated subsurface while using the site. This would be possible if the source receptor pathways were inhibited. The land-use type would be restricted to a certain extent however this could be potentially off-set by the benefits of employment opportunities generated by the need for on-site security, monitoring and maintenance. There could also be benefits from the site's use as a recreational or green area and in encouraging educational activities on the site involving the local community. These additional considerations could be added to the tools.

5. Future Research and Development Avenues

REC, SRT and the life cycle assessment method are being applied to a brownfield case study in Belgium, where two feasible technologies have been carried out at pilot scale. The objective of the study is 1) to determine the most sustainable alternative; 2) to determine where the existing approaches can be adjusted to account for the large variations in remediation duration and different land-use alternatives and 3) to determine the extent of social and indirect economic implications of different land-use scenarios on-site. The next step would be to develop indicators for these additional considerations and integrate them into existing tools.

6. Acknowledgements

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