COMBINING RISK ASSESSMENT AND LIFE CYCLE ASSESSMENT TO DERIVE REMEDIATION STANDARDS FOR SOIL CONTAMINATED BY HEAVY METALS

Deyi Hou, D. O'Connor, B. Zhao

Tsinghua University, School of Environment, Beijing, China

houdeyi@tsinghua.edu.cn

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Introduction

Heavy metal contamination is wide spread in urban areas, mining fields, and agricultural land. In China, it was estimated that 16.1% of the nation's land has soil contamination issue, with 7.0% of the soil contaminated by cadmium, 4.8% of the soil contaminated by nickel, 2.7% of the soil contaminated by arsenic, 1.6% of the soil contaminated by mercury, 1.5% of the soil contaminated by lead, and 1.1% of the soil contaminated by chromium (MEP, 2014). The heavy metal contamination poses a serious risk to human health and ecological systems, as well as food security. In recent years, the Chinese government has started to take initiative to clean-up the soils contaminated by heavy metals. Some researchers estimated that hundreds of billions of dollars will be spent on such cleanup efforts. On the other hand, recent studies in the sustainable remediation field has found that remediation operations can result in secondary impact of their own (Hou & Al-Tabbaa, 2014; Lemming et al., 2010). It is increasingly recognized that sustainability should be an inherent part of remediation decision making.

Traditionally risk assessment (RA) has been the basis of contaminated site management as well as determining soil remediation standards. In the ongoing green and sustainable remediation (GSR) movement, sustainability assessment (SA) has been used more often as a decision making support tool. The main purpose of a sustainability assessment is to gather information to allow decision makers (e.g. project managers, corporate directors, public policy makers) to manage complex systems with a holistic view, so that short-term and local considerations are balanced with long-term and regional/global considerations. Many different sustainability assessment methods have been used (Ness, Urbel-Piirsalu, Anderberg, & Olsson, 2007), among which life cycle assessment (LCA) has been the most popularly used method in the remediation field to account for life cycle impact of remediation activities. The present study intends to develop a new framework to combine RA with LCA-based SA methods, in order to derive more robust soil remediation standards.

Methods

Risk assessment estimates the probability that a person is exposed to contaminants and having health effects. According to the precautionary principle, conservative assumptions are often used to calculate the risk of an exposure scenario. Therefore, when risk assessment is used to conversely derive remediation standards, it often leads to a higher standard than what is necessary to protect an "average" person. This is justified especially given that those who live the closest to contaminated sites are often poor and less educated. However, risk assessment misses two key factors in a holistic decision making: 1) the number of people who are exposed to the contaminants; and 2) the detrimental effects, including both health effects and ecological effects, caused by upstream and downstream processes during remediation operations. To give an extreme example, a median sized lot may have a large quantity of soil with contaminant concentration slightly exceeding health risk-based standard. When health risk assessment is used as the sole decision making tool, it is natural to conclude that this bulk of soil needs to be treated. However, it is also known that only one or two employees will be working at this site after it is developed. Moreover, the remediation of the large quantity of soil requires the burning of many tons of fossil fuel in various machines and equipment, thus emitting a large quantity of air pollutants such as PM2.5 and SOx. These

PM2.5 and SOx contaminants can cause health effects to a large population. It is likely that the combined health risk posed by these secondary contaminants released in the upstream and downstream processes exceed the health risk posed by the primary contaminants at the contaminated site. However, risk assessment is not capable of evaluating this trade-off. In comparison, a LCA based study can more comprehensively evaluate the adverse effect associated with these secondary emissions. In this study, we use RA to assess the primary impact and use LCA to assess the secondary impact. Both the RA and the LCA are parameterized so that they are related to contaminant concentration and distribution at the contaminated site. The primary and secondary impacts are then compared based on the size of population that is potentially exposed to these contaminants. An "optimum" remedial standard is determined using a function that incorporate both RA and LCA results.

Results

The proposed framework can be effectively used to derive remedial standards that are more robust than those established solely based on risk assessment. It can also be used to compare different remedial options (e.g. soil washing vs. landfilling), and to identify environmental hot spots to improve the selected remedy. Some results are shown in Figure 1.

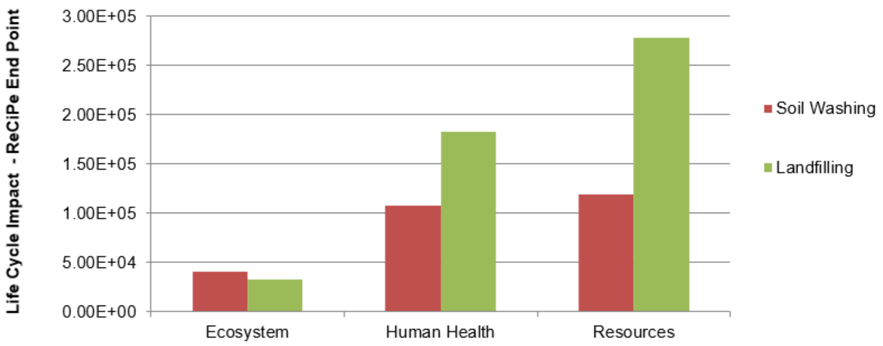

Figure 1. Life cycle assessment results for soil washing and landfilling of heavy metal contaminated soils

Conclusion

In addressing heavy metal contamination in soil, it is important to consider both the primary impact associated with site contaminants and secondary impacts associated with remedial operation. The combination of RA and LCA can be effectively used to derive remedial standards that are protective of human health and the environment.

References

Hou, D., & Al-Tabbaa, A. (2014). Sustainability: A new imperative in contaminated land remediation. *Environmental Science and Policy, 39*, 25-34.

Lemming, G., Hauschild, M. Z., Chambon, J., Binning, P. J., Bulle, C., Margni, M., & Bjerg, P. L. (2010). Environmental impacts of remediation of a trichloroethene-contaminated site: Life cycle assessment of remediation alternatives. *Environmental Science and Technology, 44*, 9163-9169. doi:10.1021/es102007s

MEP. (2014). *National Soil Contamination Survey Report*, Beijing, China.

Ness, B., Urbel-Piirsalu, E., Anderberg, S., & Olsson, L. (2007). Categorising tools for sustainability assessment. *Ecological Economics, 60*, 498-508.