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Sustainable Remediation

Paul Bardos and **Hayley Thomas,** co-chairs of the UK Sustainable Remediation Forum, look at the principal components of risk-based land management and sustainable remediation, focusing on the UK, and how this works in practice…

Contaminated land is a major global challenge. Large areas of contaminated or brownfield land exist in higher income countries, eg, ~2.5m sites are suspected across Europe[1] (300,000 of these in the UK[2], although not all of these will need remediation). 126,000 sites in the USA are thought to be sufficiently polluted as to require remediation[3]. Lower and middle-income countries also suffer substantial land contamination problems. Significant problems include persistent organic pollutants (eg, see www.ihpa.info); mercury contamination particularly from small scale gold mining; contamination of agricultural land (eg, nearly 20 percent of farmland in China is thought to be contaminated[4]) and discharges from large scale industrial complexes and processing facilities. Environmental remediation is also an important economic activity with an international market size estimated at $65bn each year[5]. Over the past 20-30 years many sites have been treated and approaches have matured in many countries. The international technical consensus is that contaminated land decision making should be made on the basis of risks to human health and the wider environment[6], and that risk management should also meet sustainable development principles[7]: sustainable risk based contaminated land management (SRBLM). This combines the use of risks as a basis for contaminated land management and the importance of managing risks in a sustainable way (aka "sustainable remediation"). In 2017, the ISO published a standard ISO/DIS 18504[8] "Soil quality – Sustainable remediation" that describes a broadly agreed approach to achieving sustainable remediation.

Land contamination has a strong connection to waste management, both in terms of being in large part a historical legacy of poor waste management practice, and also remediation being a source of waste streams, or indeed potential recyclates. The UK actually has a world-lead in managing recyclates from remediation projects through a waste management code of practice managed by CL:AIRE[9]. This short paper describes the principal components of risk-based land management and sustainable remediation, focusing on the UK, and how this sustainable and risk-based approach to land management works in practice.

Good Practice

RISK IS a function of the scale of an impact and the likelihood of that impact occurring. Risk assessment provides a logical framework for contaminated land management decisions: determining the most substantive risks and mitigating them. This allows remediation resources to be prioritised where harm is likely to be greatest. This might either be in ➥

Figure 1: courtesy of the University of Southampton

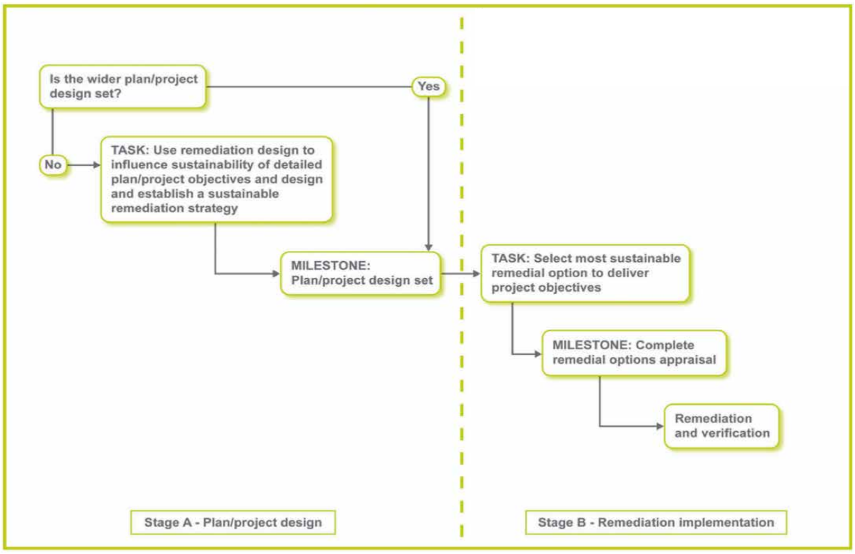
terms of determining which sites need remediation most urgently, or within a site which particular contamination issues are of the greatest impact to particular receptors such as human health, water or ecology. Understanding risks also allows decisions to be made that remediation is not needed, ie, on sites where there is no unacceptable harm[10]. For a risk to be present (see Figure 1) there needs to be a source (of hazardous substance or property), a receptor (which could be adversely affected by the contamination) and a pathway (linking the source to the receptor). A receptor might be a human, ecology, water resources, but also a building or an ecological "good or service" provided by the wider environment. This combination of a source-pathway-receptor is sometimes referred to as a contaminant (or pollutant) linkage.

Good practice in contaminated land management is to collate information about suspected or actual contaminated sites in a conceptual site model (CSM), which summarises the various contaminant linkages identified at a site. This model is developed iteratively, for example initially these contaminant linkages may be only potential pollutant linkages, and further site assessment then takes place to substantiate whether they are plausible or not. Remediation then proceeds on the basis of breaking these linkages.

Effective remediation strategies depend on a sound CSM that identifies all of the key contaminant linkages that need to be addressed to mitigate harm, and the consequent risk reduction objectives required. This makes available three broad types of intervention:

1. source management – removal or immobilisation of the source term
2. pathway management - prevention of the migration of contaminants along pathways
3. receptor management – action to prevent receptor access to a pathway, a very common approach is an "institutional control" such as a temporary prohibition of use of water from an impacted well. Typically, receptor management is less favoured as it accepts a reduction in functionality, but in some cases, it is unavoidable. Another form of receptor intervention is a planning control, such as limiting the future land use to an industrial purpose.

Figure 2



Management at the source or pathway may be by an engineering approach such as excavation and removal or containment, such as by an impermeable barrier, or a treatment-based approach. A treatment is a biological, chemical or physical intervention that either destroys, stabilises or removes contaminants.

From an idealistic point of view the preference would appear to be treatment of the source, in situ or, if necessary, *ex situ*. However, they are typically incomplete, leaving a significant proportion of the contaminant mass in-ground, especially for extractive techniques. Hence most remediation strategies combine some form of source management intervention with a pathway management intervention. As a simplified example, for fuel spills some form of extraction of the source term and enhanced bioremediation for residual source materials and dissolved substances in the groundwater pathway. This process integration provides a "belt and braces" approach to ensuring the potential of harm to receptors of concern is effectively prevented.

However, remediation interventions can be associated with significant sustainability impacts, for example transfer of contaminants to another site or to the air, energy and materials costs, impacts on local communities and often rather high economic costs. Limitations on land use can also be a significant impact. Consequently, the concept of "sustainable remediation" or "sustainable risk based land management" are also increasingly recognised.

Thought Leaders

OVER THE past 10 years or so sustainability considerations have become more widely recognised in contaminated land management, and are now formally described, and widely accepted as crucial to remediation planning and implementation. In broad terms, this is simply the application of the principles of sustainable development to soil and groundwater remediation projects. The UK has been one of the international "thought leaders" in the international development of sustainable remediation. Interest and uptake is proliferating across the world. Professionals in many national Sustainable Remediation Fora (SuRFs) and the International Sustainable Remediation Alliance (ISRA) collaborate to promote sustainable remediation on a global basis[11].

SuRF-UK define sustainable remediation as: the practice of demonstrating, in terms of environmental, economic and social indicators, that the benefit of undertaking remediation is greater than its impact and that the optimum remediation solution is selected through the use of a balanced decision-

Table 1: Benefits from a sustainable and risk based approach to contaminated land management

Benefits from a risk based approach	Additional benefits from a sustainable approach
• Objective understanding of likely harm • Methodological framework and rationale for effective remediation • Ability to prioritise resources to the most significant / urgent problems	• Better optimised risk management • Potentially additional benefits and value (eg, renewables from brownfields) • Identifying and avoiding project risks • Demonstrable compliance with government and/or corporate policies and goals for sustainable development • Positive impact on reputation/public relations and community/society

making process. Hence good practice in contaminated land management should encompass both mitigating all significant (ie, unacceptable) risks from land contamination present, but it must do so sustainably, delivering net benefit in terms of social, economic and environmental factors, and adopting a balanced and inclusive decision-making process. SuRF-UK published a UK framework for the delivery of sustainable remediation in 2010, which was welcomed by all of the regulatory authorities across the UK. It has continued to develop guidance ever since, and this is all free to view and download from www.claire.co.uk/projects-and-initiatives/surf-uk.

It would be wrong to draw the conclusion that sustainable remediation is all about "end of pipe": ie, deciding how best to manage the impacts of remediation work. It is true that in many cases the constraints surrounding a site (for example its planned built redevelopment) will dictate the risk management goals needed. In this case, the most sustainable outcome will be an optimisation of the remediation approach needed to achieve these predefined goals, what SuRF-UK describe as "Stage B". However, considering remediation earlier on in the project conceptualisation can lead to major sustainability gains, for example by redesigning the configuration of a project to avoid unnecessary or unnecessarily intensive remediation interventions. SuRF-UK describe this decision making as "Stage A" (See Figure 2). An important part of SuRF-UK's mission is to convey the importance of sustainability, and the remediation industry's contribution to this, to other professions, in particular those working in planning and development. There are really important benefits to be had from a sustainable and risk based approach to contaminated land management (see Table 1).

Government agencies have not been slow to see the added importance of sustainable remediation in better contaminated land management practice. Not only is sustainable risk-based land management optimising the environmental, economic and social outcomes from remediation, but it also helps those authorities deliver their sustainable development obligations under the Planning System and contribute to achievement of national / international sustainable development goals.

In conclusion, remediation is a necessary burden to remedy the mistakes from the past, but by applying sustainable risk based land management principles we can ensure the remediation activities themselves do not create new problems, and indeed positively contribute to achieving sustainable development. ■

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References

1. EEA, 2014 https://www.eea.europa.eu/data-and-maps/indicators/progress-in-management-of-contaminated-sites
2. House of Commons, Environmental Audit Committee, Soil Health, May 2016 https://www.publications.parliament.uk
3. National Academy of Sciences (2012) Alternatives for Managing the Nation's Complex Contaminated Groundwater Sites.
4. www.theguardian.com/environment/chinas-choice/2014/apr/18/china-one-fifth-farmland-soil-pollution
5. www.reportlinker.com/p02584389/Global-Markets-for-Environmental-Remediation-Technologies.html
6. Vegter, et al. (2002) Sustainable Management of Contaminated Land: An Overview. Report. Austrian Federal Environment Agency on behalf of CLARINET, www.commonforum.eu/publications_clarinet.asp.
7. Rizzo, Bardos *et al.* (2016) Comparison of international approaches to sustainable remediation. Journal of Environmental Management 184, 4-17
8. www.iso.org/standard/62688.html
9. www.claire.co.uk/projects-and-initiatives/dow-cop
10. Eg, as set out in the "Model procedures for the management of land contamination". Environment Agency R&D Report CLR11, 2004. Environment Agency, Bristol, UK. www.gov.uk/government/uploads/system/uploads/attachment_data/file/297401/scho0804bibr-e-e.pdf
11. www.claire.co.uk/projects-and-initiatives/surf-international

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