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Developing principles of sustainability and stakeholder engagement for "gentle" remediation approaches: The European context

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A B S T R A C T

Gentle Remediation Options (GRO) are risk management strategies or techniques for contaminated sites that result in no gross reduction in soil functionality (or a net gain) as well as risk management. Intelligently applied GROs can provide: (a) rapid risk management via pathway control, through containment and stabilisation, coupled with a longer term removal or immobilisation/isolation of the contaminant source term; and (b) a range of additional economic (e.g. biomass generation), social (e.g. leisure and recreation) and environmental (e.g. CO_2 sequestration) benefits. In order for these benefits to be optimised or indeed realised, effective stakeholder engagement is required. This paper reviews current sector practice in stakeholder engagement and its importance when implementing GRO and other remediation options. From this, knowledge gaps are identified, and strategies to promote more effective stakeholder engagement during GRO application are outlined. Further work is required on integrating stakeholder engagement strategies into decision support systems and tools for GRO (to raise the profile of the benefits of effective stakeholder engagement and participation, particularly with sector professionals), and developing criteria for the identification of different stakeholder profiles/categories. Demonstrator sites can make a significant contribution to stakeholder engagement via providing evidence on the effectiveness of GRO under varying site contexts and conditions. Effective and sustained engagement strategies however will be required to ensure that site risk is effectively managed over the longer-term, and that full potential benefits of GRO (e.g. CO_2 sequestration, economic returns from biomass generation and "leverage" of marginal land, amenity and educational value, ecosystem services) are realised and communicated to stakeholders.

1. Introduction

This paper reviews current practice in stakeholder engagement within Europe during land remediation activities, with specific focus on the application of "gentle" remediation options (GRO). We outline a remit and context for GRO application within sustainable remediation strategies, particularly where "soft" end-use of remediated land is envisaged. Findings are presented from the recently completed European Union (EU) ERA-NET SNOWMAN project SUMATECS (Sustainable Management of Trace Element Contaminated Sites) and the ongoing EU FP7 KBBE (Knowledge Based Bio-Economy) GREENLAND project. These findings encompass current sector practice in stakeholder engagement and its importance when implementing GRO and other remediation options. From this, knowledge gaps are identified, and strategies to promote more effective stakeholder engagement during GRO application are outlined.

Two broad concepts have emerged in the management of contaminated land over the past 30 years: the use of risk assessment to determine the seriousness of problems, and the use of risk management to mitigate problems found by risk assessment to be significant (Vegter et al., 2002; ITRC, 2008). For a risk to be present

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there needs to be a source (of hazardous contamination), one or more receptors (which could be adversely affected by the contamination) and one or more pathways (linking the source to the receptors). Receptors might be human health, water resources, a built construction, or the wider environment. For example, in the UK this combination of a source-pathway-receptor is referred to as a *pollutant* or *contaminant linkage* (Fig. 1, Defra, 2012). Requirements for remediation *strictly* depend on risk management needs, whether the intended use of land is for a "hard" end use such as a built development or a "soft" end use, where the soil remains unsealed (e.g. www.zerobrownfields.eu), such as community parkland. Risk management focuses on breaking the contaminant linkage, either by controlling the source (e.g. extracting the contamination from the subsurface); managing the pathway(s) (e.g. preventing migration of contamination); protecting the receptor(s) (e.g. planning or institutional controls to avoid sensitive land uses) or some amalgamation of these components.

Conventional approaches to contaminated land risk management have focussed on containment, cover and removal to landfill. However, since the late 1990s there has been a move towards treatment-based remediation strategies using *in situ* and *ex situ* treatment technologies (e.g. Dermont et al., 2008). More recently the concept of Gentle Remediation Options (GRO) has emerged. These are risk management strategies/techniques that result in no gross reduction (or a net gain) in soil functionality as well as risk management. Hence they have particular usefulness for maintaining biologically productive soils. GROs encompass a number of technologies which include the use of plant (phyto-), fungal (myco-) or microbiologically-based methods, with or without chemical additives, for reducing contaminant transfer to local receptors by *in situ* stabilisation (using biological or chemical processes) or extraction of contaminants (e.g. Ruttens et al., 2006; Grispen et al., 2006; Chaney et al., 2007; Vangronsveld et al., 2009; Onwubuya et al., 2009; Mench et al., 2010), such as phytovolatilisation, phytodegradation, phytoextraction, rhizofiltration, phytostabilisation and mycoremediation. A similar concept might also exist for groundwater (for example monitored natural attenuation might be considered a GRO). As a concept GROs are a development of an earlier idea called "extensive" technologies which sought to distinguish low input longer term remediation approaches from energy and resource intensive strategies (Bardos and van Veen, 1996).

Biologically productive soils include those used for agriculture, habitat, forestry, amenity, and landscaping, and therefore GROs will tend to be of most benefit where a "soft" end use of the land is intended. Conventionally regeneration of contaminated land for soft end use has involved the use of cover systems with revegetation and/or removal of contamination hot spots (Cairney and Hobson, 1998). Remediation (i.e. treatment-based mitigation of contaminants using biological, chemical or physical processes) has been largely restricted to returning smaller land areas to hard re-use as these treatments simply tend to cost too much for soft end uses.

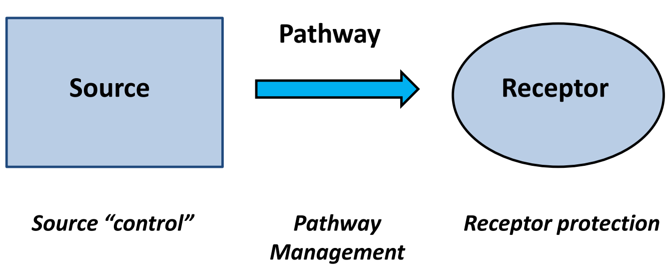

Fig. 1. Contaminant linkage and risk management options (based on Defra, 2012).

There are many drivers for soft end uses of contaminated land. The site in question may simply not have a feasible alternative use for reasons of size, location, geotechnical or topographical reasons, or levels of economic activity, as a result of global shifts in land use and industrial change (Menger et al., 2012). There may be important urban renewal arguments for developing amenity land, particularly in areas of urban deprivation (Handley, 1995; National Urban Forestry Unit, 2001). In addition, there may also be opportunities for generating renewed economic activity, for example, through biomass production. Indeed, the recent EU Renewables Directive (DIRECTIVE 2009/28/EC) points out an enhanced sustainability value for biomass from marginal land. The use of GROs can be highly compatible with biomass end use (e.g. Bardos et al., 2008; Puschenreiter and the SUMATECS consortium, 2009; Bardos et al., 2011b; Van Slycken et al., 2013a,b). This creates an important and expanding niche for GROs, as an important part of the value proposition for the management of degraded land in the future might be an income from biomass-based GRO (Puschenreiter and the SUMATECS consortium, 2009).

GROs may therefore offer a cost effective treatment alternative for managing risks for soft end uses, rather than simply containing or transferring contamination. GROs appear to be attractive alternatives to conventional cleanup methods in these situations owing to their relatively low capital costs and the inherently aesthetic nature of planted or "green" sites (ITRC, 2009). In addition, "greening" of contaminated or marginal land may have additional wider benefits in terms of educational value, CO_2 sequestration, resource deployment (as a compost re-use) and providing a range of ecosystem services (e.g. Bardos et al., 2011a; Witters et al., 2012). However, the application of GROs as practical site solutions is still in its relative infancy, despite a substantial research investment. The barriers to wider adoption, particularly in Europe, arise both from the nature of GROs, and market perceptions of uncertainties over whether these methods can achieve effective risk management in the long term.

The majority of remediation work in Europe has been carried out as a result of regulatory demand for critical risks and/or to stimulate the re-use of brownfield land. Hence unsurprisingly, most funded remediation and brownfield regeneration projects are in or around urban environments, and brownfields re-use is strongly driven by economic factors. These projects are often constrained by pressure on timescale and relatively limited site areas. Both of these factors have tended to exclude consideration of GROs which are perceived as slow and more suited to large area problems.

The time taken before prescribed "total" concentration-based risk management targets such as soil quality thresholds are reached is also seen as a limitation for GROs. This has led to intensive discussions in particular about phytoextraction, which is perhaps the most well-known GRO, and which has been widely tested at demonstration scale (e.g. Vangronsveld et al., 2009; Mench et al., 2010). Phytoextraction has tended to be seen as a source management activity which seeks to gradually remove trace elements from soil over time into biomass. Phytoextraction has poor acceptance as a functional source management tool because contaminant removal may take decades and there is some concern over the fate of and contaminant concentration in harvested biomass (e.g. Van Slycken et al., 2013a,b). Acceptance of other GROs related to phytostabilisation and *in situ* immobilisation is limited because source removal does not take place, and there is a perception that stabilisation or immobilisation are potentially reversible over time (e.g. Onwubuya et al., 2009 – see also detailed reviews in Vangronsveld et al., 2009; Puschenreiter and the SUMATECS consortium, 2009; Mench et al., 2010).

The constraints on acceptability of GROs seem inevitable when remediation success is judged solely using generic soil