CL:AIRE

SUB 2
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subr:im bulletin

CL:AIRE's SUBR:IM bulletins present practical outcomes of research by the SUBR:IM consortium which have direct application to the brownfield and contaminated land communities. This bulletin investigates the sustainability of remediation through the development and use of a sustainability assessment methodology.

Uncovering the True Impacts of Remediation

1. INTRODUCTION

Remediation is sustainable. Or is it? Cleaning up contaminated land allows redevelopment of derelict sites, helps to remove urban blight, removes risks to health and safety and reduces urban sprawl and greenfield development. All contribute to what might popularly be called a sustainable outcome, but are there other factors that have to be considered? And what if those that have been mentioned are not fully achieved? Is sustainability something that is ever considered when designing remediation projects? This bulletin describes work performed as part of Work Package E of the SUBR:IM (Sustainable Urban Brownfield Regeneration: Integrated Management) research consortium, investigating the sustainability of remediation through the development of a sustainability assessment methodology for comparing and assessing different remediation technologies and projects and identifying their impacts.

2. SUSTAINABILITY AND THE REMEDIATION INDUSTRY

Until recently, civil engineering-based remediation methods, particularly 'dig & dump', were the most popular, due to their low cost and ease of use. However, the implementation of the landfill tax and the EU Landfill Directive has led to an increase in cost and a reduction in available landfill space for hazardous waste such as contaminated soil. As a result, other remediation methods are beginning to establish themselves. Process-based techniques such as bioremediation, soil washing and stabilisation/solidification are now increasing in popularity in the UK. Such techniques are often considered 'sustainable' as they have reduced impacts over excavation and disposal to landfill, but their full impacts are usually not considered.

Historically the major concerns in selecting a remediation technique have been cost and feasibility. This is beginning to change with a greater appreciation of environmental and social impacts. In a 2004 survey of UK industry practitioners including local authorities, consultants, contractors and other interested parties, the awareness of and the extent to which sustainability is considered in remediation projects was investigated based on a total of 60 responses. Figure 1a shows how the tenets of sustainability are being considered when selecting remediation technologies, incorporating wider environmental, social and economic impacts as well as what happens in the long term. It is apparent that all areas are regularly taken into consideration, but the question is: to what extent? Commonly, the effects of contamination on these areas both immediately and in the long term are taken into account, but those of actually performing the remediation (transportation, waste etc) are often not and so progress towards a truly sustainable solution is hindered.

An important part of determining whether a project is to be sustainable is ensuring that all potential impacts are considered when the project is designed. The tools used to select a suitable remediation technology are therefore important. Figure 1b shows the extent to which certain tools or approaches have been utilised. As would be expected, professional judgement is exercised most commonly; concern might be raised over those who say they only use it 'often' or 'sometimes', although this is largely because other techniques are used to provide the answers. Environmental impact and cost/benefit analyses are frequently used, but more complex methods for which there is less guidance or legislation are less common. Life-cycle analysis in particular is rarely used at present. However, a life-cycle based approach is necessary in order to fully assess

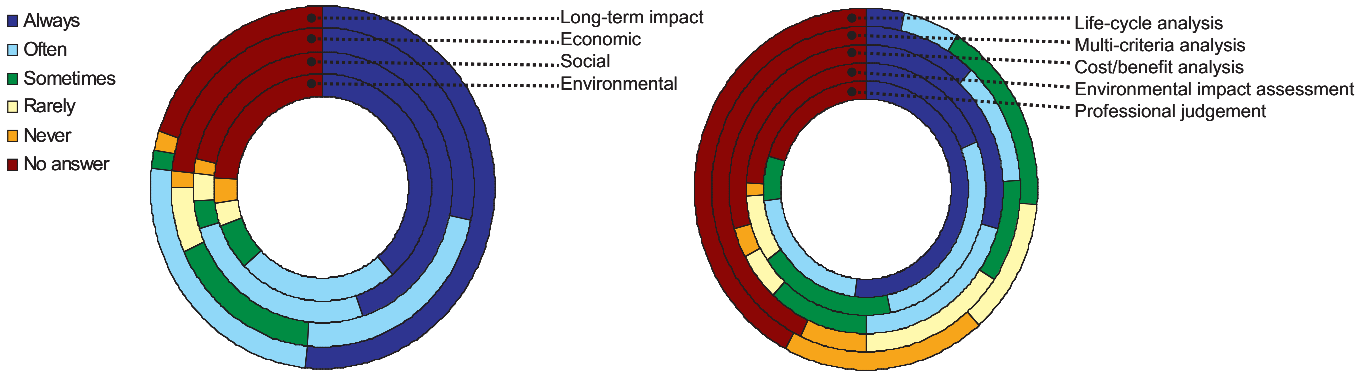

Figure 1a (left). Summary of questionnaire responses to the question: "Do you consider the sustainability of any aspects of a project in the selection of a remediation technology?" Figure 1b (right). Summary of questionnaire responses to the question: "What methodologies do you or have you used in helping you to determine the best remediation technology for a particular project?"

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the true impacts of remediation, and as such it is likely that the full impacts are often neglected.

Sustainability is clearly beginning to be appreciated by remediation practitioners, although the extent to which this is expressed in terms of building it into remediation projects is unclear. It is likely that certain areas are incorporated, particularly on larger projects where the cost implications are not so onerous or where regulations require it. However, it is equally likely that many areas are not considered, perhaps because important data is not available or there is no appreciation of the potential effects. As such, the true impacts of remediation technologies are not widely appreciated.

3. METHODOLOGY AND APPLICATION

An appreciation of the true impacts of different remediation technologies would be valuable in the design of sustainable remediation projects. The methodology presented here has been developed and used to identify where technical and environmental impacts arise in order to inform decision-making in such ventures and is based around four broad criteria:

- *Criterion 1: Future benefits outweigh cost of remediation.* This requires any benefits of the remediation to outweigh any costs over the lifetime of the project and beyond. Benefits and costs measured in non-financial terms include risks to site users and public, quality and quantity of surface water, groundwater, air and soil, use of non-renewable resources, non-recyclable waste and potential range of future uses of the land. Financial benefits include economic value of the land, impact on surrounding areas and incentive/tax break. Costs include capital, operation and maintenance, labour, site investigation, monitoring/post-closure maintenance, professional fees, insurance/legal and off-site disposal.

- *Criterion 2: Environmental impact of the implementation of the remediation process is less than the impact of leaving the land untreated.* The environmental impacts of the 'remediation' and 'no action' options in terms of reducing or removing the risks of contamination to receptors should be measured and compared using factors such as future risk to human health, impact on ground conditions, impact on water flow, air pollution, flora and fauna, restriction on future use of the land, impact on other sites, landscape and fate of the contaminants.

- *Criterion 3: Environmental impact of bringing about the remediation process is minimal and measurable.* This deals with the implementation of the remediation process itself, rather than the effect of contamination, and requires such impact to be minimal. This includes impacts of all the processes involved including transport, emissions to air, energy use, use of secondary materials, waste, direct use of natural resources and impact of the materials used in the remediation process. All impacts need to be measurable.

- *Criterion 4: The time-scale over which the environmental consequences occur, and hence inter-generational risk, is part of the decision making process.* Factors include long-term monitoring and maintenance, post-closure maintenance, durability, future underground activities, land management issues, long-term contaminant degradation and sustainable use of the soil.

Whilst these criteria address the physical impacts of remediation and the effect on contamination, pathways and receptors, specific social and economic impacts have not been addressed directly. However, the physical causes of these impacts would be included. The methodology could be expanded to incorporate these areas if required.

The range of technologies that potentially can be used for remediation is necessarily large to address the huge variability in contamination, soil properties (chemical, physical and biological) and groundwater conditions. Therefore any assessment of the impacts of such techniques has to be wide ranging and able to consider a wide variety of potential impacts that might arise as a result of their implementation. A methodology has been developed that incorporates a multi-criteria analysis (MCA) and a detailed impact analysis (DIA), both of which take a life-cycle approach (see Harbottle et al., 2005, 2006, 2007 for more details). This includes impacts not obviously connected with remediation but occurring as a direct consequence of it (e.g. in raw material excavation), both on immediate and long-term timescales. Applying the assessment methodology to completed remediation projects allows a realistic assessment of technologies and facilitates the identification of particular problems with technologies which can then be used in the design procedure of future remediation projects.

The MCA takes an overview of a project and allows inclusion of both quantitative and qualitative effects. It is based on an Environment Agency method for selecting optimal remediation technologies for a particular site (Postle et al., 1999), where a number of categories of information are scored, weighted and summed. The categories and sub-categories that have been included to date are listed below, although these could be expanded upon if required.

- Human health and safety (risks to site users; risks to public)
- Local environment (surface water quality and quantity; groundwater quality and quantity; air quality (pollution); quality and structure of soil; habitat and ecology)
- Stakeholder concern (acceptability of remediation)
- Site use (duration of works; impacts on landscape; future site use; surrounding land use)
- Global environment (air quality (greenhouse gases); natural resource use; waste)
- Cost (taking into account changes in land values as well as the cost of remediation).

Scores are developed for each sub-category, for both the site itself and any ancillary sites and for both during and after remediation in both those cases. They can be based either on quantitative or qualitative information. The relative importance of each sub-category and category for a particular site is then incorporated through the use of weights, and these are then combined to give a final overall score.

The DIA compares projects on individual sub-categories to identify where the major impacts are for particular methods. Primarily quantitative data such as emissions, waste or material use can then be compared on an individual basis to identify where the major areas of impact arise for particular techniques. In both cases the use of the life-cycle approach means that impacts on other sites are also considered, and this means that work on landfills and other ancillary sites is included in the analysis.

The methodology has deliberately not adhered to a rigid format or set of indicators, but is amenable to alteration and to the inclusion of other factors. Therefore, although only technical and environmental impacts have been largely considered so far, there is considerable scope for expansion, bringing in social and wider economic aspects of a project. The outcome of a detailed assessment and comparison of the impacts of *in situ* stabilisation/solidification, excavation and disposal to landfill and taking no action on the same site are presented here as an example of how the developed methodology can be applied. Full details of this work are presented elsewhere (Harbottle et al., 2005, 2006, 2007). A detailed assessment and comparison of five different remediation technologies on five different sites based on five completed remediation projects is currently being completed.

4. CASE STUDY

The case study presented here compared the advantages and disadvantages of using *in situ* stabilisation/solidification (S/S), excavation and disposal to landfill or of taking no action on a contaminated site. The site in question was remediated using S/S, although excavation and disposal was considered and hence there are data available for both cases. The 'no action' option assumed that the site conditions remained the same as prior to remediation. A summary of the options is provided in Table 1. Excavation and disposal to landfill has been included in this study as it is still a commonly used remediation technique and is usually assumed to be inherently unsustainable, and is hence used as a baseline for comparison. A common unit of measure has been employed; each quantitative measure or score has been normalised with respect to the tonnage of soil remediated on the site. The methodology also allows the inclusion of effects on sites other than that being remediated (e.g. landfills or borrow pits).

Table 1. Brief details of the options being compared.

Project	Details
In situ Stabilisation/ solidification	A cement-based binder material was used to treat contaminated areas. Auger rigs with hollow flight augers were used to deliver and mix the binder with the soil in situ. The *in situ* nature of the project meant that no waste material was produced and the majority of the work was performed on the site itself.
Excavation and disposal to landfill	All contaminated material (the same volume as was treated with S/S) was assumed to have been removed through excavation followed by disposal at a suitable landfill. The excavated material was replaced with virgin fill.
No action	No contaminant removal or containment was attempted prior to redeveloping the site.

The site itself was previously used for industrial purposes, which had contaminated the coarse-grained soil layers to a depth of ~4m with organic contaminants, particularly BTEX (benzene, toluene, ethylbenzene and xylenes). The site was to be redeveloped for residential use, and potential receptors included future site residents and a nearby river.

The outcome of the MCA is presented in Figure 2. Scores give indications of the change in impact due to remediation (i.e. if there is no change before and afterwards then there is a zero score). The scores from six main categories (human health and safety, local environment, stakeholder concern, site use, global environment and cost) are presented. Each is made up of weighted scores from a number of sub-categories. Positive scores can be interpreted as 'good' and negative as 'bad'. It can clearly be seen that excavation and disposal to landfill produced some highly negative scores compared to *in situ* S/S and no action, with 'cost', 'human health and safety' and 'global environment' providing particular cause for concern. This is perhaps not surprising; the technique has long been considered to be particularly unsustainable. In comparison, S/S performed well. Overall, the 'cost' category scored well as the benefits of redevelopment outweighed the cost of performing the remediation. The major negative impact of this technique was that of greenhouse gas emissions (as indicated by the performance of the 'global environment' category in Figure 2), due to carbon dioxide release in cement production. Otherwise, the *in situ* nature of the remediation helped to minimise a number of potentially onerous impacts, such as those arising from transportation and waste. The main impacts with the 'no action' option were in the 'stakeholder concern', 'site use' and 'local environment' categories. As there would be little change in both the effects on human health and costs/land values these have a low score and are not visible on the figure.

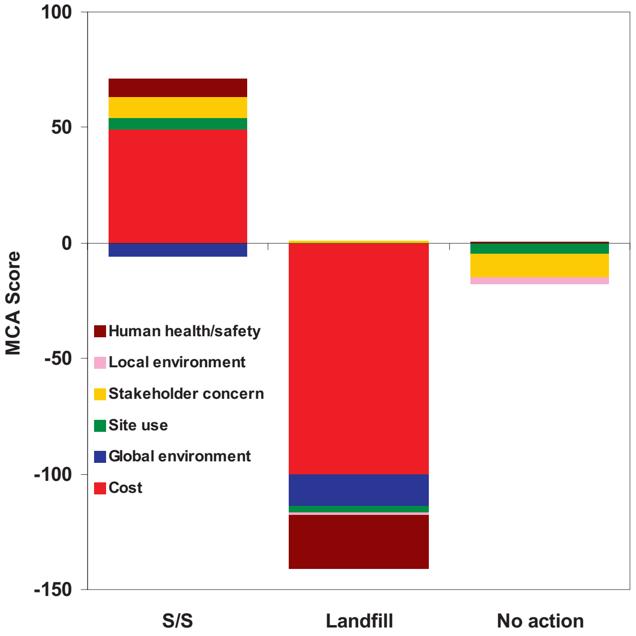

Figure 2. Outcome of the multi-criteria analysis. The scores on each of the six categories are presented (stacked data), which are in turn based on scores and weights from a number of sub-categories.

The results of the MCA allow the comparison of broad categories of data. It allows both quantitative and qualitative data to be included in a single analysis, although the latter includes the risk of a certain degree of subjectivity. An assessment of individual sub-categories has also been performed in the DIA to further investigate these broad scores. This covers a number of areas such as emissions, waste production, contamination risks and long-term effects. Examples of the data are given in Figure 3 for use of raw and recycled materials impacts and in Figure 4 for transportation impacts. Figure 3 shows the relatively small amount of raw material usage with S/S when compared to the fill required in the excavation and disposal to landfill. The larger total material usage with S/S (including reused site soil) indicates the increase in density of the treated soil. Figure 4 shows how an *in situ* remediation technique significantly reduces road usage compared to that required to dispose of the material off-site. In both examples presented here, taking no action has no impact.

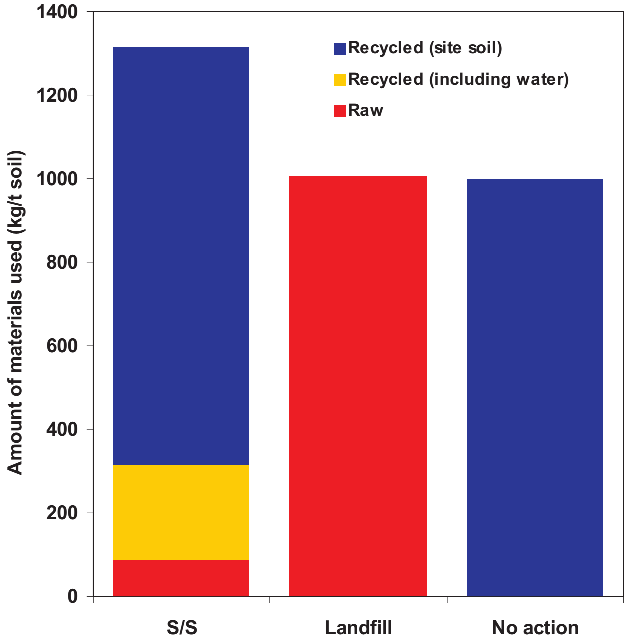

Figure 3. Total recycled and raw materials in the detailed impact analysis.

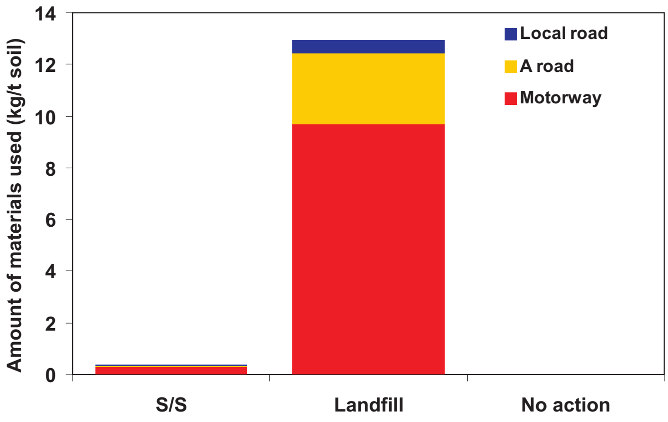

Figure 4. Transportation requirements, broken down into road type, in the detailed impact analysis.

A summary of the outcome from the DIA is presented in Table 2, listing the main impacts of each of the three remediation scenarios assessed. Excavation and disposal to landfill had a number of negative impacts that arose through its intensive on-site work and extensive use of off-site transportation and disposal. These include emissions from transport and site work, use of materials, considerable waste production and potential long-term effects of contamination in the landfill. Despite the ease of use of this technique and the thoroughness with which the remediated site is cleaned, it would still be expected to have considerable concern for stakeholders, particularly those who live near the landfill site. S/S has a mixture of low and high impacts; emissions are high due to cement production but this is offset by the reduction in site and off-site work required. S/S also has long-term impacts, as the contaminants remain on the site itself and as such may pose a future risk to site users. Taking no action has serious impacts with respect to the effects of the contamination on receptors, but of course it involves no work in implementing it and so has no impact on many of the sub-categories considered in this analysis.

Table 2. Summary of impacts, both positive and negative, of the technologies used in case study projects.

In situ stabilisation/solidification	Excavation and disposal to landfill	No action
• Low intensity operations • Low waste • Low transportation • Low noise • High CO_2 emissions • High energy use • Contaminants remain • Changes to soil properties	• High transportation • High waste production • High material use • Impacts on landfill site • High energy use • Long duration • High disturbance	• Stakeholder concern • Continued risks to site users • Impact on river quality

5. SUMMARY AND CONCLUSIONS

The objective of this work was to identify and compare the wider impacts of a range of remediation technologies in use in the UK. A methodology was developed based on multi-criteria and detailed impact analyses, both of which incorporated life-cycle approaches. This was used to compare three options on a particular site, and highlighted the major impacts from each, with the excavation and disposal to landfill project performing poorly and the *in situ* stabilisation/solidification project performing comparatively well. Both the excavation and the off-site disposal portions of the former technique had significant impacts, both of which where minimised by performing S/S *in situ*. Full assessment and consideration of sustainability or of wider impacts of remediation is not currently performed in practice, although the results from the survey show that awareness of sustainability issues exists and that certain aspects are being implemented. It is hoped that the analysis presented here will assist in informing the selection of remediation technologies through knowledge of their true impacts in tandem with their efficacy and cost.

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For further information please contact the authors:
Dr Michael Harbottle, Geoenvironmental Research Centre, Cardiff School of Engineering, Cardiff University.
Email: Harbottlem@cardiff.ac.uk
Dr Abir Al-Tabbaa, Department of Engineering, University of Cambridge.
Email: aa22@eng.cam.ac.uk