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The adoption of sustainable remediation behaviour in the US and UK: A cross country comparison and determinant analysis

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HIGHLIGHTS

- Ranked 27 sustainability considerations in remediation in the US and the UK.
- Ranked promoting factors and barriers of sustainable remediation.
- Identified internal characteristics and external forces affecting GSR behaviour.
- Determined the statistical significance of each factor's effect.

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ABSTRACT

The sustainable remediation concept, aimed at maximizing the net environmental, social, and economic benefits in contaminated site remediation, is being increasingly recognized by industry, governments, and academia. However, there is limited understanding of actual sustainable behaviour being adopted and the determinants of such sustainable behaviour. The present study identified 27 sustainable practices in remediation. An online questionnaire survey was used to rank and compare them in the US ($n = 112$) and the UK ($n = 54$). The study also rated ten promoting factors, nine barriers, and 17 types of stakeholders' influences. Subsequently, factor analysis and general linear models were used to determine the effects of internal characteristics (i.e. country, organizational characteristics, professional role, personal experience and belief) and external forces (i.e. promoting factors, barriers, and stakeholder influences). It was found that US and UK practitioners adopted many sustainable practices to similar extents. Both US and UK practitioners perceived the most effectively adopted sustainable practices to be reducing the risk to site workers, protecting groundwater and surface water, and reducing the risk to the local community. Comparing the two countries, we found that the US adopted innovative in-situ remediation more effectively; while the UK adopted reuse, recycling, and minimizing material usage more effectively. As for the overall determinants of sustainable remediation, the country of origin was found not to be a significant determinant. Instead, organizational policy was found to be the most important internal characteristic. It had a significant positive effect on reducing distant environmental impact, sustainable resource usage, and reducing remediation cost and time ($p < 0.01$). Customer competitive pressure was found to be the most extensively significant external force. In comparison, perceived stakeholder influence, especially that of primary stakeholders (site owner, regulator, and primary consultant), did not appear to have as extensive a correlation with the adoption of sustainability as one would expect.

1. Introduction

Land is not only a critical component of the earth's life support system, but also a precious resource and an important factor of production in economic systems. However, historical industrial operations have resulted in huge swathes of contaminated land that are only slowly being remediated. The US was estimated to have 294,000 hazardous waste sites needing cleanup (USEPA, 2004), and the European Environmental Agency (EEA) estimated that its member countries have 246,000 sites with soil contamination requiring cleanup (EEA, 2007). In the UK, England and Wales were estimated to have 33,500 contaminated sites (EA, 2005). These contaminated sites represent a huge risk to the welfare of current and future generations. Both the UK and the US governments have ambitious plans for cleaning up their tens to hundreds of thousands of contaminated sites within the next few decades (Rogers, 1999; USEPA, 2002). However, at the current investment pace, it may take many decades, if not centuries, to clean up these historical sites

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(USEPA, 2004). It is imperative to develop technical solutions as well as socioeconomic and political instruments to achieve sustainable restoration of contaminated land while preventing the further contamination of existing clean lands (Hou, 2011; Hou et al., 2012b). While historically remediation focused on the removal and/or control of risks, there has been a recent shift towards sustainable practices within the remediation industry. The concept of "sustainable remediation" is increasingly accepted by remediation practitioners (Ellis and Hadley, 2009; Petruzzi, 2011; Lubrecht, 2012), as well as governments (CLARINET, 2002; USEPA, 2010; ITRC, 2011b) and academia (Harbottle et al., 2008; Sparrevik et al., 2012; Owsianiak et al., 2013; Hou et al., 2014). The inclusion of sustainability concepts in remediation decision-making also provides an opportunity to integrate a wide range of considerations: risk control, brownfield regeneration, carbon footprint, water footprint, renewable energy, etc.

There is considerable variability in the adoption of sustainability in remediation practice in various countries (Maurer, 2009). The UK plays a leading role in promoting sustainable remediation in Europe. In the most recent revision to the UK's contaminated land statutory guidance, a key policy objective was to ensure that the remediation burdens are "compatible with the principles of sustainable development" (DEFRA, 2012). Two UK based organizations, CLAIRE and Surf-UK, have been active in advocating sustainable remediation not only in the UK, but also Europe-wide. In 2010, Surf-UK, with coordination of CLAIRE and sponsorship from the Home and Communities Agency of the UK government, developed a framework for assessing the sustainability of remediation strategies (Surf-UK, 2010). The sustainable remediation agenda in the UK was also promoted by the urban renaissance movement. Driven by a public policy mandating that 60% of new housing development should be built on brownfield land, England had 79% of dwellings built on previously developed land in year 2008 (DCLG, 2009). The sustainable remediation, or green remediation, concept did not win recognition in the US until very recently. The presidential Executive Orders (EO) 13423 and 13514, issued in January 2007 and October 2009 respectively, promoted sustainable measures in federal agencies' operations. In 2008, the USEPA published a technology primer on green remediation that incorporates sustainable practices in contaminated site remediation (USEPA, 2008). It was followed by subsequent sustainable remediation initiatives in many other government agencies and industrial associations (DTSC, 2009; Ellis and Hadley, 2009; USEPA, 2009; Favara et al., 2011; Holland, 2011; Holland et al., 2011; ITRC, 2011b; USEPA Region 10, 2012; USEPA Region 2, 2012; USEPA Region 9, 2012; Illinois EPA, 2012; Minnesota PCA, 2012; Oregon DEQ, 2012). It should be noted that there are also differences in "green remediation" which is promoted by the USEPA and focuses on reducing environmental footprint of remediation operations, and "sustainable remediation" which is more widely accepted in Europe and incorporates social, economic, and environmental sustainability (ITRC, 2011b; Hou and Al-Tabbaa, 2014).

While many initiatives have taken place to promote sustainable behaviour in the remediation field, little is known on how effectively such sustainable behaviour has been adopted, and what may affect its adoption. In the present study, data from a survey of remediation practitioners was used to compare the adoption of sustainable remediation in the US and UK. The survey primarily focused on the US and the UK, mainly because these two countries have relatively large remediation markets and they both have shown strong interest in sustainable remediation, as evidenced by government policies and guidance (USEPA, 2008; ITRC, 2011b; DEFRA, 2012), as well as industrial initiatives in these two countries (Ellis and Hadley, 2009; Surf-UK, 2010). The survey also collected information on organizational properties, individual characteristics, institutional forces, and stakeholder influences. Subsequently, multivariate statistical analysis was conducted to identify potential determinants of the adoption of sustainable behaviour. This study aims to provide insights for sustainable behaviour, to researchers, policy makers, and practitioners, not only in the remediation field, but also in the wider sustainability field. The present study is built on the social, economic and environmental tripartite model. It is recognized that many other sustainability models exist (Kates, 2010), but the tripartite model is selected due to its wide acceptance in the sustainable remediation community.

2. Materials and methods

2.1. Survey design

2.1.1. Sustainability considerations

Sustainability is an overarching concept with many practical implications. In the remediation field, various guidance documents, whitepapers, and policies have provided a wide range of sustainability considerations (EURODEMO, 2007; USEPA, 2008; Ellis and Hadley, 2009; Surf-UK, 2009; USACE, 2010; ITRC, 2011b). Based on an extensive review of existing literature, the present study identified 27 sustainability considerations, which were rated by respondents in the questionnaire survey (see Supporting Information [SI]). Some of these sustainability considerations tended to be generic. They were selected to maximize their potential of being incorporated into a wide range of contexts (e.g. across multiple countries and multiple work types). Consequently some specific sustainability practices, such as remedial process optimization (Hou and Leu, 2009), were not included in this survey. In addition, the selected sustainability considerations span across social, economic, and environmental spectrums. The survey question was "how effective is your team in adopting the following 'sustainability' considerations in developing remediation strategies?", and the responses were given on a 5-point scale (1: not at all — 5: very effective). It should be noted that this list of sustainability considerations was not built on a systematic and exclusive literature review; therefore, it by no means represents all potential sustainable remediation considerations. However, the authors believe that this list represents the majority of sustainable remediation considerations that are commonly accepted by the sustainable remediation community.

2.1.2. Internal characteristics and external forces

In the present study, potential determinants of sustainable behaviour were classified into two groups: internal characteristics and external forces. The internal characteristics represent the internal features that are associated with the decision maker (i.e. respondent), while the external forces represent the outside conditions faced by them. Internal characteristics studied in the present study covered three levels: the personal level (professional role, professional experience, and personal belief), organizational level (organization size, and organizational policy), and societal level (the US or the UK). Three types of external forces were measured in this survey: promoting factors, barriers, and stakeholder influences. For promoting factors, the survey question was "How important are the factors listed below in motivating your team to adopt sustainable practices in remediation?", and responses were given on a 5-point scale (1: not at all — 5: very important). For barriers, the survey question was "Have the following barriers impeded your team in adopting sustainable practices in remediation?", and responses were given on a 5-point scale (1: not at all — 5: very significant). Detailed descriptions of all these variables and the corresponding questionnaire items are provided in SI.

2.2. Survey procedure

The survey questionnaire was designed following extensive literature review on sustainable remediation, and according to general questionnaire survey guidance (Brace, 2004; Dillman, 2007; Saris and Gallhofer, 2007). The pilot questionnaire test was conducted with ten remediation practitioners and based on their feedback, the questionnaire was revised. A finalized survey questionnaire was setup online and emailed to potential survey participants. The survey included a