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Research article

Assessing the trend in sustainable remediation: A questionnaire survey of remediation professionals in various countries

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ABSTRACT

Over the past decade, sustainable remediation has grown from an emerging concept into a widely accepted new institutional norm. Scholar literature increased exponentially from nearly none in late 1990s to over 400 publications per year in 2014. The present study used a questionnaire survey conducted in 2012 and 2014 to assess the global trend in the awareness and practice of sustainable remediation. A total of 373 responses were received from survey participants located in 22 countries. The survey found that the US and the UK similarly had the highest level of awareness and adoption rate of sustainable remediation. Asia and other developing countries had much lower awareness levels and/or adoption rates. For all regions, the adoption rates were significantly lower than awareness levels, indicating a large gap between awareness and practice. One specific example is regarding minimizing greenhouse gas emission, which is a focal point in sustainable remediation literature, but with very low adoption rate according to this survey. This study also found that the adoption rates of a few sustainable remediation considerations, such as "minimizing local scale secondary impact", "minimizing national to global scale secondary impact", and "bringing prosperity to disadvantaged community", had decreased between 2012 and 2014. On the other hand, the survey also suggests the remediation community has rendered more expertise, training, and resources in sustainable remediation between 2012 and 2014. The mixed results suggest that in order to enhance sustainable remediation adoption, it is imperative to employ continued effort to enhance the understanding of sustainable remediation by practitioners and to link self-interest and public interest with sustainable remediation considerations.

1. Introduction

Contaminated sites are a huge liability in both developing and developed countries. In the United States (US), it was estimated that around 294,000 sites will require cleanup over the next 30 years (USEPA, 2004), including 9 million hectares of contaminated land overseen by the US Environmental Protection Agency (USEPA) (USEPA, 2010), and over 1300 National Priority List sites (USEPA, 2013). In England and Wales, it was estimated that 300,000 ha, or 2% of the land area of England and Wales, may be contaminated, including 781 identified "contaminated land" sites and 35 "special sites" (EA, 2009). In China, the land contamination issue is far more serious than what has been observed in western countries. According to the recent report from China's Ministry of Environmental Protection (MEP), 16.1% of the nation's land has been polluted with contaminants ranging from arsenic and cadmium to polycyclic aromatic hydrocarbon and dichlorodiphenyldichloroethane (DDD) (MEP, 2014). These contaminated lands pose a risk to both human health and ecological systems.

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. Sustainable remediation of contaminated sites has drawn much attention from governments, industry, and academia in recent years. Many white papers and technical guidance have been published by various organizations and government agencies (Ellis and Hadley, 2009; ITRC, 2011; CL:AIRE, 2010; USACE, 2010). Under the influence of such institutional forces, remediation professionals are motivated by public interest as well as self-interest to comply with new norms and rules (Hou and Al-Tabbaa, 2014; Prior, 2016). A number of academic studies have been published on issues like sustainability assessment, life cycle assessment (LCA) and sustainable technology

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development (Bardos, 2012; Bardos et al., 2011; Hou et al., 2014b; Madejón et al., 2011; Witters et al., 2012; ASTM, 2013). A search on Google Scholar indicates that the number of publications pertaining to sustainable remediation has grown exponentially over the last decade (see Fig. 1).

Even though literature on sustainable remediation has grown substantially, there are research gaps in the sustainable remediation field which have impeded its adoption, due to an inability to quantify social and economic sustainability (Ellis and Hadley, 2009; ITRC, 2011) and tertiary impacts (Morais and Delerue-Matos, 2010), the lack of transferrable sustainability assessment results (Hou et al., 2014c), and the lack of understanding of practitioners' actual behavior (Hou et al., 2014a). It is also noted that there are country variations in research needs as stakeholders in some countries prefer to qualitative assessment rather than quantitative socioeconomic impact analysis. The actual behavior of remediation practitioners is of particular interest; however, they are often driven more by socioeconomic and regulatory factors rather than technical factors. On the other hand, the reaction of decision makers to socioeconomic and regulatory constraints are subjective rather than objective. Therefore, it is necessary to study the behavior pattern of remediation practitioners in order to maximize the potential for sustainability in remediation. A better understanding in this arena can guide policy making, as well as technology development.

This study intends to examine the spatial and temporal variation in the adoption of sustainable remediation. Existing studies have shown that there are variabilities in the adoption of sustainable remediation practices among different countries (Hou et al., 2014a; Maurer, 2009). However, these studies are limited to a small number of countries. In addition, there is no comparison over time. The present study uses a questionnaire survey conducted in 2012 and 2014, with respondents from 22 countries, to conduct a spatial and temporal analysis. This study aims to provide an empirical assessment of the global trend in sustainable remediation, in order to provide insights on sustainable behavior, to researchers, policy makers, and practitioners.

2. Materials and methods

2.1. Questionnaire design

A questionnaire survey was designed to gauge the adoption of sustainable behavior by remediation practitioners. Based on an extensive review of various sustainable remediation guidance documents, whitepapers, and policies (Ellis and Hadley, 2009; EURODEMO, 2007; ITRC, 2011; CL:AIRE, 2009; USACE, 2010; USEPA, 2008), a total of 27 sustainable behaviors were identified. These sustainable behaviors were identified based on the following criteria: 1) they are mentioned in more than one references listed above to ensure their broad acceptance; 2) they are applicable to the general remediation community rather than any one specific country context; and 3) they can be used to gauge behavior rather than simply technological measures. Moreover, a pilot study was used to ensure that these sustainable behavior measures can be interpreted by remediation practitioners. The adoption of each sustainable behavior was measured in the questionnaire by asking: "how effective is your team in adopting the following 'sustainability' considerations in developing remediation strategies?" The responses were given on a 5-point scale. The anchors were "not at all" (1) and "very effective" (5). In addition, the promoting forces and barriers, identified from the review of existing literature, were measured by two questions. The promoting forces were based on the question: "How important are the factors listed below in motivating your team to adopt sustainable practices in remediation?" The responses were given on a 5-point scale. The anchors were "not at all" (1) and "very effective" (5). The barriers were based on the question: "Have the following barriers impeded your team in adopting sustainable practices in remediation?" The anchors were "not at all" (1) and "very significantly" (5).

The survey was initially conducted in 2012. In 2014, the questionnaire was revised and the survey was conducted again. The revised questionnaire included several new questions to gauge the respondent's perception of sustainable remediation adoption in their home country, in addition to the questions pertaining to their own behavior. The revised questionnaire also included questions to measure how often and what kind of tools the respondents used to conduct sustainability assessment in the respondents practice. Due to paper length limit, these additional survey questions are only briefly described in the results section.

2.2. Survey procedures

The survey was conducted according to general questionnaire survey guidance (Brace, 2004; Dillman, 2007; Saris and Gallhofer, 2007). A pilot questionnaire test was conducted. In the pilot study, the draft questionnaire survey was sent to seven remediation professionals for testing. The pilot test participant was asked to

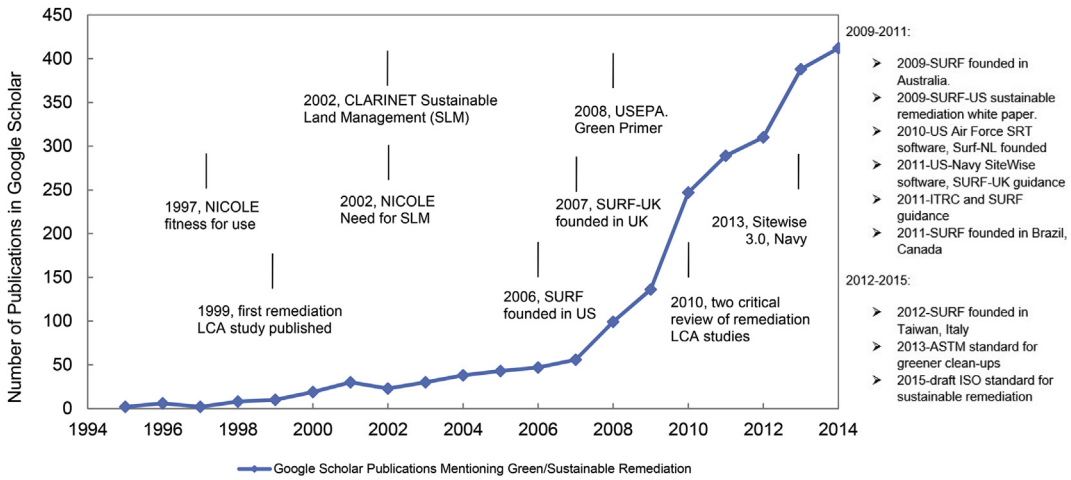

Fig. 1. Exponential growth in sustainable remediation publication and historical events.

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