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ORIGINAL ARTICLE

Divergence in stakeholder perception of sustainable remediation

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Abstract The modern society is increasingly demanding sustainable practices in engineering fields. In the specific case of engineering practices for restoring contaminated land, there is an ongoing sustainable remediation movement which has rapidly drawn attention from both the industry and governments. It is well recognized that decision making in contaminated land remediation depends on the interaction of a variety of stakeholders. However, there is still no consensus as for how various stakeholders perceive sustainable practices in remediation, and how stakeholders interact in decision making that may lead to sustainable practices. The present study proposes a hypothetical model depicting the mediating effect of stakeholder perception in decision making. Using empirical experiences, questionnaire survey, and qualitative interview results, the present study found that there is divergent perception by various stakeholders regarding how sustainable behavior is adopted and how it is affected by stakeholder influence. The divergent view was attributed to varying organizational objectives, information access, and self-perception. Moreover, it found that incorporating sustainability into real engineering practice is transdisciplinary and requires transdisciplinary processes that can help various stakeholders to reach consensus.

Keywords Sustainability · Environmental behavior · Contaminated land remediation · Stakeholder perception · Transdisciplinary

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Introduction

This study examines how stakeholders perceive sustainable behavior as well as their influence on promoting sustainable behavior in the remediation industry. The past two decades have witnessed substantial research work in both the natural science spectrum and the social science spectrum to help ensure progress toward sustainable societies (Kates et al. 2000; Levin and Clark 2010; Bettencourt and Kaur 2011). It has fostered research understanding on technologies, policies, and human behavior. In this new era of transdisciplinary research, it is increasingly recognized that sustainable development warrants a better understanding of human attitude and human behavior, which determines the effectiveness of government policies aiming at pollution prevention and environmental restoration (Mihelcic et al. 2003; Hou 2011; Hou et al. 2012b). A better understanding of human attitude and behavior can also lead to a better understanding of technological innovation and the diffusion of environmental friendly technologies (Geroski 2000).

The perception literature suggests that psychological (Stoll-Kleemann et al. 2001; Jackson 2005), social (Steg et al. 2001), and institutional (Blake 1999) barriers exist which have impeded the adoption of sustainable behavior. On an individual level, most environmental problems are not immediately tangible and require the perception of language, pictures, and graphs (Kollmuss and Agyeman 2002). Moreover, intangible environmental issues like greenhouse gas emission tend to be perceived to be distant in space and time (Lorenzoni et al. 2007). On an organizational level, companies' commitment to sustainability is often dependent on managerial perception of sustainability (Hahn and Scheermesser 2006; Hou et al. 2014a). Given the importance of perception in guiding action, scholars have started exploring how to encourage the change in perception (e.g. using visualization tools, marketing pro-environmental behavior according to their perceived effort and difference) as a means to drive behavior change (Sheppard 2005; McDonald and Oates 2006).

On the other hand, it is known that human judgment and decision making are distorted by perceptional biases (Pronin 2007). Perception studies suggest that people's existing mindsets, particularly the perception of the necessity and effects of mitigation actions, can affect how people interpret new information (Lorenzoni et al. 2007). Skepticism and ignorance tend to occur when such sustainable behavior conflicts with existing values and experiences (Stoll-Kleemann et al. 2001). People are reluctant to change their behavior to be more sustainable when they have a perception that other people are not taking such actions, i.e. worrying about free riding (Lorenzoni et al. 2007). People tend to resist changes when they are not sure about the consequence of sustainable behavior. However, when people perceive that the problem is being solved, they maybe more convinced of the advantage of policies that encourage sustainable behavior (Steg and Gifford 2005).

This paper intends to examine human attitude and human behavior in a single industry context. The study is transdisciplinary in that it intends to identify the realities between disciplines and beyond disciplines, where much scientific information exists but yet to be found. The remediation industry provides a unique opportunity for exploring this subject because it involves enhanced interactions among key stakeholders (i.e. site owner, regulator, and consultant). In addition, remediation practitioners have a high level of sustainability awareness, and this field offers a potential to progress to advanced sustainability practices. The adoption of the newly emerged "sustainable remediation" and/or "green remediation" is even more unique in that it is largely driven by non-mandatory government policies and self-initiated industrial voluntary actions. Therefore, it provides a unique context in examining how societal pressures rather than mandatory regulatory forces can promote the transition to sustainable societies. The success of this transition relies upon the transformation of consumption patterns by both individual consumers and institutional consumers. The recent sustainable remediation movement represents a transformation of consumption pattern by institutional consumers, more specifically in infrastructure engineering practices. Within this context, it is crucial to better understand the underlying mechanisms that promote the adoption of sustainable practices.

This paper proposes that stakeholder perception and their perceived influence play an important role in sustainable remediation decision-making processes. Based on results from a survey of remediation practitioners, the study examined the divergent views of different stakeholders on the effectiveness of adopting sustainability in remediation, and further tested whether the perceived stakeholder influence differs in various stakeholders' views. It is anticipated that with a better understanding of stakeholder perception, sustainability policies and programs could be designed to align better with important stakeholder's interests and capability. Based on the analysis of stakeholder divergence, the paper further argues that the sustainable remediation movement urgently needs transdisciplinary process to truly incorporate sustainability into the decision making and engineering practices.

Data and methodology

Sustainable remediation and a hypothetical model of stakeholder interaction

Land contamination is a major challenge to modern society; with an estimated 294,000 contaminated sites in the United States (US) (USEPA 2004) and nearly 3 million potentially polluted sites in Europe (Bardos et al. 2011). Historically remediation was considered inherently a sustainable practice. Prior to the emergence of the remediation field, industrial sites contaminated by historical operations were typically redeveloped with potentially toxic chemicals buried underneath. These toxic chemicals, such as heavy metals, pesticides, and other organic pollutants, can be absorbed by human bodies through dermal contact, ingestion, and inhalation, leading to severe human health problems (NRC 1991). The release of these toxic chemicals can also damage ecological systems (Chapman 2002). Various countries have established mandatory regulations and policies to govern the redevelopment of such contaminated brownfields (Gong 2010). Remediating contaminated sites mitigates these risks posed to human health and the environment. In addition, remediation reduces urban sprawl and greenfield development, consequently modern green design standards, such as the Leadership in Energy and Environmental Design program, recognize brownfield remediation as a major credit toward sustainable development (USGBC 2011). Therefore, remediation is generally considered an inherently sustainable practice. On the other hand, remediation operations may also be associated with secondary adverse effects like noise and air pollution during construction, and other environmental impacts ranging from local scale to global scale. Consequently these remediation operations are not necessarily sustainable (Al-Tabbaa et al. 2007).

During recent years, the concept of "green and sustainable remediation" has emerged and draws much attention. In a framework developed by SURF-UK (a sustainable remediation network established in 2007 in the UK) and CLAIRE (a remediation network founded in 1999 in the UK), sustainable remediation is considered "remediation that eliminates and/or controls uncontrollable risks in a safe and timely manner, and which maximize the overall environmental, social, and economic benefits of the remediation work" (Surf-UK 2010). While the sustainable remediation concept is still evolving, various stakeholders have been engaged in advocating the green and sustainable remediation. Regulators have been at the forefront of the current green and sustainable remediation movement. In Europe, policy makers advocate a risk-based approach to achieve sustainable management of contaminated land (CLARINET 2002a, b; Common Forum 2010). The UK has built sustainability considerations into its remediation regulations. In the 2012 Contaminated Land Statutory Guidance (i.e. on the contaminated land regime under Part 2A of the Environmental Protection Act 1990), being "compatible with the principles of sustainable development" is put as one of the three overarching objectives of the government's policy, parallel to the objective of "identify and remove unacceptable risks to human health and the environment" (DEFRA 2012). In the US, presidential Executive Orders 13423 and 13514 promote sustainable means 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). The USEPA Office of Solid Waste and Emergency Response, a lead federal agency that oversees the Superfund program as well as the Brownfields program, set its policies to encourage sustainable remediation (USEPA 2009). Similar green remediation policies and practices have also been adopted by several EPA regions and state governments. These regulations and policies from regulators have great influence in promoting sustainable remediation practices.

It is generally recognized that the success of sustainable remediation largely depends on stakeholder engagement (Ellis and Hadley 2009; ITRC 2011). The interaction of stakeholders depends on their own perspectives and objectives, as well as their perception of outcomes and the influences of other stakeholders. Figure 1 presents a hypothetical model showing how stakeholder action and project outcome are mediated by stakeholder's perception of project outcome, their own influence, and other stakeholders' influence. Studies have shown that stakeholder perception and influence provide useful constructs for examining organizational behavior (Freeman 1984; Delmas and Toffel 2004). Exploring the perception of stakeholders might reveal both the capability and willingness of each stakeholder to promote sustainable practices (Garvare and Johansson 2010; Gordon et al. 2012; Kerselaers et al. 2013). For instance, residents' perception of tourism development impact was found to significantly affect residents' attitude for additional tourism development (Ko and Stewart 2002). In another study, perceived risk and underlying perceptive affecting factors were found to be vital for the choice of preferred remediation alternative by stakeholders (Sparrevik et al. 2011). Public perception was also found to affect their willingness to pay in cleaning up contaminated sites (Alberini et al. 2007). The capability of a stakeholder to influence decision making depends on not

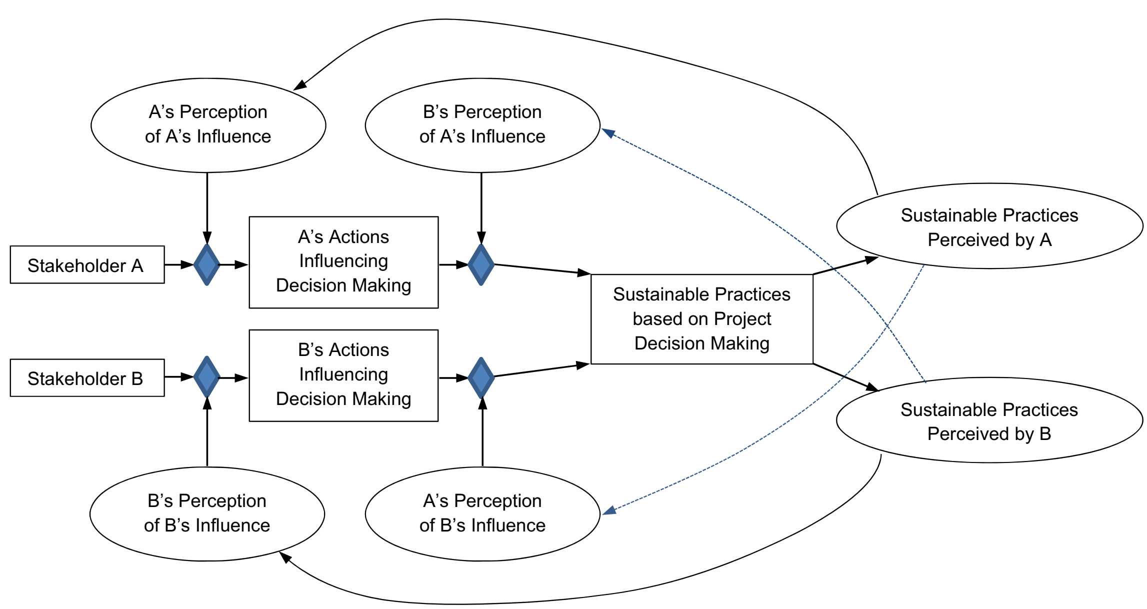

Fig. 1 A hypothetical model of perception mediated decision making and influence on sustainable practices

only their own action, but also how other stakeholders perceive this stakeholder's influence. On the other hand, the willingness of a stakeholder to promote sustainable practice depends on their satisfaction with relevant practice, as well as the degree in which they perceive their influence on ultimate decision making. Moreover, the various stakeholders are usually from different disciplines, and there are often disciplinary barriers in the communication. The purpose of this research was to improve the understanding of stakeholder interaction in a complex environment, and to assist policymakers in designing policy instruments and programs to promote sustainable practices via transdisciplinary collaboration.

Data collection

An online survey questionnaire was conducted between July and October, 2012. Two questions were included in the survey to better understand the perceived effectiveness of sustainability adoption, as well as the perceived importance of various stakeholders in affecting such decision making. The first question was: "how effective is your team in adopting the following 'sustainability' considerations in developing remediation strategies?" The responses were given on a 5-point Likert scale. The anchors were "not at all" (1) and "very effective" (5). There were 27 sustainability considerations which were rated by each respondent. The second question was regarding stakeholder influence on the adoption of sustainable remediation (5-point scale, with anchors "no influence" Alberini et al. 2007 and "very strong influence" Blake 1998). A total of 17 types of stakeholders were rated by each respondent in the survey.

A link to the online survey was sent to potential participants by emails. The invitation letter included a cover letter explaining the objective of the survey, and assured that the confidentiality of respondent would be guaranteed. To encourage participation, the participants were offered a future summary report of aggregated results to those who explicitly expressed interest. In addition, several reminder emails were sent to all participants who had not responded, or who started, but not finished responding. The target population included all stakeholders involved in environmental remediation decision making and/or practices. The survey participants were mainly contaminated site owners, regulators, and environmental consultants, but also included contractors, technology vendors, environmental groups, etc. While the survey was sent to remediation practitioners worldwide, the study intended to put a primary focus on the US, the UK, and China. The survey was directly sent to 1480 potential participants through individual emails. In addition, the survey was promoted on newsletters sent by professional organizations and online remediation forums, and additional participants were solicited in a snow-ball fashion. A response rate of 9.5 % was estimated based on individual contacts that were tracked. A variety of procedures were used in the survey to promote response rate. Based on analysis of variance tests, these procedures did not lead to biased results, with the exception of the offering of a survey summary report as an incentive, which may have led to a bias high of respondent ratings as for the adoption of sustainable practices.

Following the questionnaire survey, qualitative interviews were conducted with 28 remediation practitioners in the US (10), UK (10), and China (8). Junior and middle level professionals (junior and middle level engineers, scientists, and managers) as well as senior level professionals (e.g. senior engineers, principle geologists, senior managers, and company executives) were represented. Attempts were also made to interview people with awareness and a strong interest in sustainable remediation, as well as people with poor awareness or weak interest in sustainable remediation. Forty letters were sent to invite interview participants, and distribution was stopped when 28 people had agreed to participate, mainly due to the limit of time. The interview was semi-structured, with a list of open-ended questions asked in all interviews. Issues arising during the interviews were pursued through follow-up questions. The structured question list reduces research bias within the study, and the open-ended questions allow participants to fully express their viewpoints and experiences. A pilot test was conducted on six participants. The question list and interview procedures were improved based on the pilot test results. The interview and analysis followed a series of guidance set out in existing literature (Hammer and Wildavsky 1989; Burnard 1991; Weiss 2008).

Data analysis

Responses were classified according to the type of stakeholders they represent. A total of 15 choices were provided on the list of stakeholders, but no survey participant indicated that they fell in the categories of "site user" and "site neighbor". Based on the responses received and a preliminary analysis, the respondents were classified into five groups of stakeholders: (1) site owner, (2) regulator, (3) primary consultant, (4) other working parties (OWP), including contractors, technology vendors, specialty consultant, drillers, laboratories, equipment vendors, and treatment reagent suppliers, and (5) academic and environmental groups (AEG). Subsequently, the average ratings of each type of stakeholder giving on each survey question were calculated. The standard error of the average rating was also calculated.

Hypothesis testing was conducted using a bootstrapping method-based independent-sample *t* test. The randomization tests were performed using SPSS software (IBM 2011). The bootstrapping algorithm is to randomly draw samples from the original data repeatedly to calculate the target statistics, such as sample mean, and then to derive test statistics and related confidence intervals. The bootstrapping method assumes that the variability in a statistical property of the dataset, for example, the mean difference of two groups of sample, will be mimicked by the variability in the same property of a large number of resampled datasets. In comparison with a conventional independent-sample *t* test, the bootstrapping-based method is advantageous in that it does not have any distribution assumptions of the data; therefore, it renders more robust hypothesis testing results.

Results

Divergent stakeholder view of adopting sustainable practices

As shown on Fig. 2, the average score on environmental sustainability, based on 18 items, and the average score on social-economic sustainability, based on 9 items, were generally similar in the five groups of stakeholders' view. All average scores fell in between 3 and 4, with site owner having higher ratings and AEG having lower ratings. When individual sustainability considerations were examined (see Table 1 and Fig. 3), there were more divergent views, which bring both benefits and challenges to stakeholder engagement (see "Divergence in stakeholder views" section for more discussion).

Six considerations are viewed to be reducing immediate environmental impact that is imminent in time and space. Significant divergent views are shown on "minimizing contaminants left behind", for which OWP gave a rating of 4.31 while site owner gave a rating of 3.50, suggesting remediation workers are more confident in the contaminants being removed by their actions, while liability owners are more concerned about residual contaminants. Overall, on the sustainability considerations concerning the reduction of immediate environmental impact, site owner and regulator viewed that these considerations are relatively well taken care of, while AEG viewed that they are more poorly addressed, implying that internal stakeholders are more confident than external stakeholders in how well such environmental impacts are addressed. One exception is that site owner recognized that "minimizing contaminants left behind" was poorly addressed. Another interesting finding is that primary consultant viewed that these considerations are relatively poorly addressed with the exception of "protect groundwater and surface water". Among the considerations viewed to be reducing distant environmental impact that is far away either in time or space, for "minimizing waste generation", the primary stakeholders gave similar ratings (3.63–3.85), but OWP gave much higher rating (4.24). This suggests that the remediation workers who actually work on the ground (e.g. contractors) see less opportunity in further reducing waste generation than those who design or oversee remediation. In "minimizing water consumption" and "conserve natural resources", regulator gave the lowest ratings (2.93 and 3.07), while site owner and OWP gave the highest ratings (3.50–3.67). Overall, concerning the reduction of distant environmental impact, regulator was relatively unsatisfied while OWP tended to be the most satisfied. Among the six considerations viewed to represent sustainable resource usage, "using sustainable energy" and "generating electricity from by-products" both had ratings below three by all stakeholders and had the lowest rating by OWP; "minimizing material use" had the lowest rating by site owner and AEG and had the highest rating by OWP. Overall, stakeholders tended to give low ratings for the adoption of sustainable resource usage measures; and the stakeholders' view on these sustainability considerations was generally more consistent.

There are three items reflecting social responsibility considerations. On "bringing prosperity to disadvantaged community", the primary stakeholders' views were more divergent, with site owner giving the highest rating (2.83)

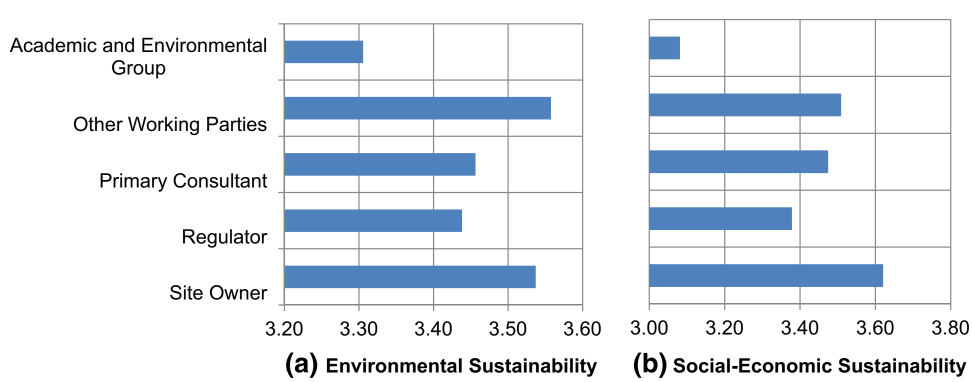

Fig. 2 "How effective is your team in adopting the following 'sustainability' considerations in developing remediation strategies?" (average score of 18 environmental sustainability considerations (**a**) and 9 social-economic sustainability considerations (**b**), on a 5-point Likert scale with 1 denoting "not at all" and 5 denoting "very effective")

Table 1 Perceived adoption of sustainability considerations by various stakeholders

	Site owner	Regulator	Primary consultant	OWP	Academic and environmental group
Reducing immediate environmental Impact					
Minimizing contaminants left behind	3.50 (0.34)	4.07 (0.20)	3.87 (0.08)	4.31 (0.10)	3.73 (0.25)
Minimizing local scale secondary environmental impacts (e.g. noise, dust, odor, local air quality, traffic, etc.)	4.17 (0.21)	4.33 (0.12)	3.88 (0.10)	3.95 (0.15)	3.73 (0.24)
Reducing local community risk	4.50 (0.15)	4.41 (0.13)	4.16 (0.10)	4.35 (0.11)	3.92 (0.19)
Minimizing risk to ecological systems	4.00 (0.33)	4.11 (0.16)	3.76 (0.11)	3.91 (0.14)	3.65 (0.19)
Protect groundwater and surface water	4.33 (0.19)	4.30 (0.13)	4.30 (0.08)	4.11 (0.15)	4.00 (0.24)
Protect habitat and ecosystem	4.17 (0.21)	3.81 (0.23)	3.96 (0.09)	3.98 (0.14)	3.62 (0.22)
Reducing distant environmental impact					
Minimizing waste generation	3.83 (0.30)	3.63 (0.23)	3.85 (0.09)	4.24 (0.13)	3.42 (0.21)
Minimizing national to global scale secondary environmental impacts (e.g. greenhouse gas emission, fossil fuel depletion, etc.)	3.00 (0.37)	3.00 (0.23)	3.00 (0.10)	3.16 (0.14)	3.04 (0.24)
Using in situ remediation rather than ex situ remediation	3.42 (0.31)	3.44 (0.20)	4.04 (0.10)	4.07 (0.16)	3.62 (0.22)
Minimizing water consumption	3.67 (0.36)	2.93 (0.18)	3.24 (0.10)	3.55 (0.15)	3.08 (0.20)
Conserve natural resources	3.50 (0.44)	3.07 (0.20)	3.40 (0.09)	3.58 (0.16)	3.35 (0.22)
Using environmental friendly products	3.17 (0.30)	3.19 (0.12)	3.06 (0.11)	3.60 (0.15)	3.65 (0.19)
Sustainable resource usage					
Enhancing reuse and recycling	3.50 (0.29)	3.44 (0.22)	3.37 (0.10)	3.62 (0.15)	3.19 (0.21)
Using sustainable energy	2.75 (0.43)	2.78 (0.22)	2.38 (0.10)	2.29 (0.14)	2.35 (0.21)
Minimizing material use	2.75 (0.52)	3.00 (0.21)	3.22 (0.09)	3.40 (0.17)	2.73 (0.25)
Minimizing energy use, increasing energy efficiency	3.25 (0.37)	2.81 (0.19)	3.08 (0.10)	3.22 (0.16)	3.12 (0.19)
Using monitored natural attenuation rather than active remediation	3.83 (0.24)	3.41 (0.23)	3.75 (0.10)	2.91 (0.19)	3.31 (0.23)
Generating electricity from by-products such as methane gas	2.33 (0.41)	2.15 (0.25)	1.89 (0.11)	1.80 (0.15)	2.00 (0.19)
Social responsibility					
Enhance local employment	3.08 (0.36)	2.89 (0.27)	2.84 (0.12)	2.76 (0.17)	2.35 (0.21)
Bring prosperity to disadvantaged community (increase tax revenue, education, security, etc.)	2.83 (0.34)	2.59 (0.25)	2.25 (0.10)	2.42 (0.18)	2.42 (0.22)
Encourage public participation and stakeholder involvement	3.67 (0.40)	3.74 (0.16)	3.52 (0.11)	3.09 (0.18)	3.12 (0.27)
Reducing remediation cost					
Minimize long-term management (e.g. monitoring) requirement	3.58 (0.29)	3.81 (0.21)	3.63 (0.09)	3.84 (0.13)	3.35 (0.21)
Using fast-track remediation alternative	3.33 (0.28)	3.22 (0.19)	3.49 (0.10)	3.84 (0.16)	3.27 (0.23)
Reducing life cycle cost	3.50 (0.40)	2.85 (0.24)	3.67 (0.09)	3.93 (0.14)	3.65 (0.28)
Increase development value					
Maximize area for redevelopment	3.83 (0.24)	3.67 (0.18)	3.92 (0.10)	3.85 (0.17)	2.92 (0.27)
Reducing site worker's risk	4.67 (0.19)	4.44 (0.14)	4.40 (0.07)	4.35 (0.11)	3.81 (0.21)
Increase property value	4.08 (0.29)	3.19 (0.21)	3.54 (0.11)	3.51 (0.17)	2.85 (0.23)
Sample number	12	27	103	55	26

Values outside of parenthesis represent average scores on a 5-point Likert scale with 1 denoting "not at all" and 5 denoting "very effective"; values inside of parenthesis represent standard errors

while primary consultant giving the lowest rating (2.25). This is likely due to the fact that site owners tend to be more familiar with site redevelopment processes (e.g. conceptualization of possible redevelopment scenarios). Three items were used to reflecting remediation cost related considerations, for which OWP gave the highest ratings (3.84, 3.84, and 3.93). The primary stakeholders gave similar ratings on all three items, with the exception of regulator who gave a rating of 2.85 on "reducing life cycle cost" versus site owner' rating of 3.50 and primary consultant' rating of 3.67. As shown in Table 2, among the three development value considerations, "reducing site worker's risk" had the highest overall rating. For this item, primary stakeholders and OWP all gave similar ratings (4.35–4.67), but AEG gave much lower rating (3.81). Again, this may reflect the fact that external stakeholders

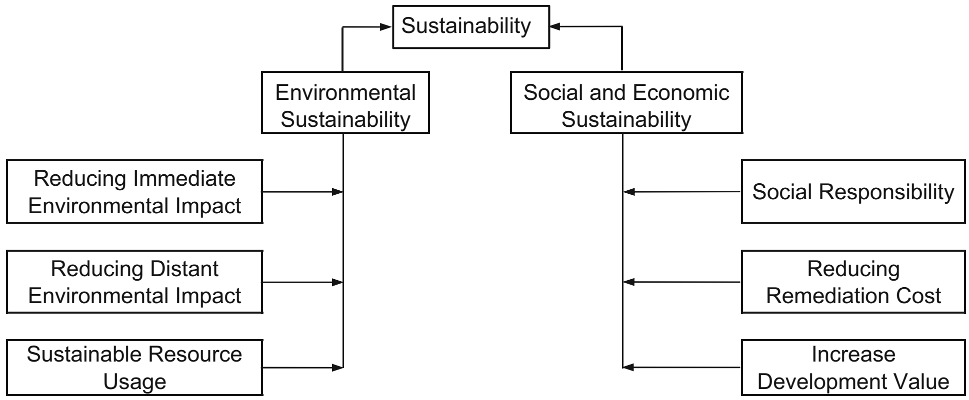

Fig. 3 Six categories of sustainability considerations in environmental remediation

Table 2 Perceived stakeholder influence in adopting of sustainability considerations

	Site owner	Regulator	Primary consultant	OWP	Academic and environmental group
Primary stakeholders					
Site owner/manager	3.33 (0.47)	3.74 (0.24)	3.71 (0.12)	3.44 (0.18)	3.65 (0.29)
Regulator	2.25 (0.35)	3.74 (0.29)	3.00 (0.12)	3.05 (0.20)	3.65 (0.30)
Primary consultant	2.42 (0.34)	3.33 (0.21)	3.61 (0.12)	3.31 (0.16)	3.04 (0.23)
OWP					
Major construction contractor	2.00 (0.35)	2.93 (0.23)	2.12 (0.10)	2.53 (0.18)	2.62 (0.24)
Key technology vendor	2.17 (0.32)	2.56 (0.22)	2.53 (0.10)	2.98 (0.17)	2.69 (0.27)
Sub-tier consultant	2.08 (0.34)	2.30 (0.21)	1.95 (0.09)	2.38 (0.15)	2.15 (0.23)
Minor construction contractor	1.83 (0.27)	1.89 (0.17)	1.67 (0.09)	1.95 (0.14)	2.12 (0.21)
Minor technology vendor	2.00 (0.33)	1.89 (0.17)	1.82 (0.09)	2.07 (0.15)	2.12 (0.22)
Local community					
Local community	2.08 (0.36)	3.15 (0.22)	2.53 (0.11)	2.47 (0.16)	2.96 (0.24)
Environmental groups	2.25 (0.37)	2.81 (0.26)	2.47 (0.12)	2.51 (0.17)	2.58 (0.21)
Neighboring property owner	1.83 (0.34)	2.74 (0.20)	2.13 (0.10)	2.29 (0.17)	2.81 (0.24)
Media	2.00 (0.30)	2.48 (0.22)	2.04 (0.11)	2.40 (0.16)	2.92 (0.24)
Institutional field actor					
Competitors	2.17 (0.24)	1.85 (0.19)	2.68 (0.12)	2.45 (0.15)	2.46 (0.21)
Professional organisations	2.67 (0.33)	2.74 (0.20)	2.76 (0.12)	2.64 (0.17)	2.54 (0.24)
Academic	2.83 (0.34)	2.00 (0.18)	2.29 (0.11)	2.45 (0.18)	3.38 (0.25)
Intra-organization stakeholders					
Top management of the Organization	3.08 (0.43)	2.67 (0.29)	3.32 (0.13)	3.31 (0.20)	3.31 (0.26)
Other employees in the Organization	2.75 (0.43)	2.81 (0.23)	2.88 (0.12)	2.56 (0.17)	2.62 (0.25)
Sample number	12	27	103	55	26

Values outside of parenthesis represent average scores on a 5-point Likert scale with 1 denoting "no influence" and 5 denoting "very strong influence"; values inside of parenthesis represent standard errors

are less familiar with the rigorous health and safety procedures that remediation workers are following. Similar situation exists for "maximizing area for redevelopment", with higher similar score given by the first four groups of stakeholders (3.67–3.92), and much lower rating by AEG (2.92). More divergent views exist for "increasing property value", for which site owner had the highest rating (4.08), primary consultant and OWP had lower ratings (3.54 and 3.51), and regulator and AEG had the lowest ratings (3.19 and 2.85).

Perceived stakeholder influences

The 17 types of stakeholders were classified into five categories, as shown in Fig. 4, according to a factor analysis. The divergent stakeholder view on stakeholder influences

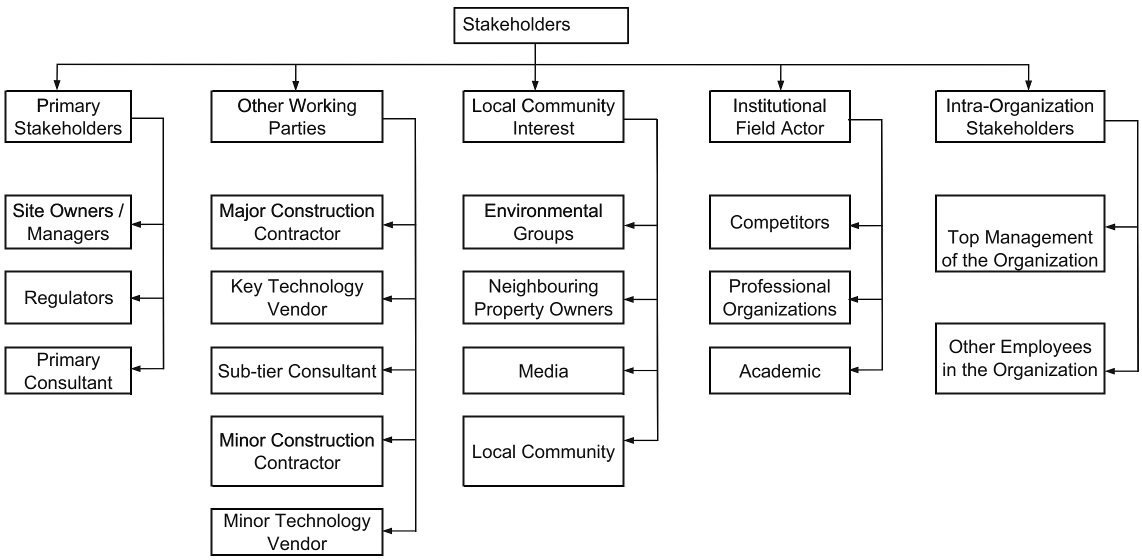

Fig. 4 Five types of stakeholders in influencing the adoption of sustainability considerations in environmental remediation

is presented in the following five corresponding subsections (also see Table 2). These survey results provide a resource for exploring how various stakeholders perceive the influence exerted by these internal and external stakeholders.

Site owner was perceived to have the overall strongest influence in adopting sustainable practices, with the highest rating by all five groups of stakeholders. This is understandable because the site owner is the liability holder and pays for the remediation work. As for regulator' influence, site owner viewed it to be weak with a rating of 2.25, but regulator themselves viewed it to be as strong as 3.74, while primary consultant rated it at a middle point of 3.00. As for primary consultant' influence, both regulator and primary consultant themselves gave a relatively high rating (3.33 and 3.61), but site owner gave it a relatively low rating of 2.42. Overall, each primary stakeholder tended to rate their own influence to be relatively strong.

Stakeholders were consistent in giving relatively high ratings for major construction contractor and key technology vendor, and giving relatively low ratings for minor construction contractor and minor technology vendor. Stakeholder views were divergent in that regulator and OWP generally gave higher ratings for the influence of these working parties than what site owner and primary consultant gave. For instance, regulator and OWP rated major construction contractor's influence at 2.93 and 2.53, while site owner and primary consultant rated this influence at 2.00 and 2.12. Four groups of stakeholders were interpreted to represent local community interests: local community, environmental groups, neighboring property owner, and media. Regulator gave relatively high ratings for all these stakeholders. In comparison, primary consultant gave nearly half point lower ratings while site owner gave nearly one point lower ratings on the influences of most of these stakeholders. These results suggest that public participation has limited effect on remediation practice, and most likely pressure from the public is transmitted via regulators. While all other stakeholders considered that the media had relatively weak influence (2.00–2.48), AEG viewed that the media had relatively strong influence (2.92). As for competitors' influence, primary consultant gave relatively high rating while site owner and regulator gave relatively low rating. As for the influence of academic stakeholders, AEG gave high rating (3.38), while regulator and primary consultant gave low rating (2.00 and 2.29). There are two types of intra-organization stakeholders: top management of the organization and other employees in the organization. It appears that top management had relatively strong influence for all stakeholders (3.08–3.32) but regulator (2.67). While all other stakeholders perceived that top management had stronger influence than other employees, regulator viewed that other employees had stronger influence than top management. These results imply that regulators may be influenced more by "peer pressure" rather than "managerial pressure" in comparison with practitioners in other types of organizations.

Bootstrapping test results

Bootstrapping tests were mainly conducted on three groups of stakeholders: regulator ($n = 27$), primary consultant ($n = 103$), and OWP ($n = 55$). Site owner was not included in bootstrapping testing because the sample number is small ($n = 12$) and hypothesis testing based on such a small number would lack statistical power. Regulator was compared against primary consultant, both as primary stakeholders, but one as public stakeholder and one as private stakeholder. As Table 3 shows, regulator gave significant higher ratings than primary consultant on these sustainable practices: minimizing local scale secondary environmental impact, using sustainable energy, and bring prosperity to disadvantaged community; while primary consultant gave significantly higher rating than regulator on these sustainable practices: using in situ remediation rather than ex situ remediation, maximizing area for redevelopment, and increasing property value. Table 4 shows that regulator gave higher rating on stakeholder influence than primary consultant, on six types

Table 3 Test results of divergent stakeholder view—sustainable practices

	Mean difference Regulator versus primary consultant	Mean difference Primary consultant versus other working parties
Reducing immediate environmental impact		
Minimizing contaminants left behind	0.13	−0.49** ($p = 0.002$)
Minimizing local scale secondary environmental impacts (e.g. noise, dust, odor, local air quality, traffic, etc.)	0.38* ($p = 0.012$)	−0.13
Reducing local community risk	0.10	−0.13
Minimizing risk to ecological systems	0.14	0.01
Protect groundwater and surface water	−0.07	0.05
Protect habitat and ecosystem	−0.09	0.06
Reducing distant environmental impact		
Minimizing waste generation	−0.21	−0.34* ($p = 0.046$)
Minimizing national to global scale secondary environmental impacts (e.g. greenhouse gas emission, fossil fuel depletion, etc.)	0.20	−0.27
Using in situ remediation rather than ex situ remediation	−0.52* ($p = 0.034$)	−0.07
Minimizing water consumption	−0.33	−0.18
Conserve natural resources	−0.26	−0.08
Using environmental friendly products	−0.11	−0.38* ($p = 0.033$)
Sustainable resource usage		
Enhancing reuse and recycling	0.00	−0.20
Using sustainable energy	0.41* ($p = 0.088$)	0.03
Minimizing material use	−0.23	−0.28
Minimizing energy use, increasing energy efficiency	−0.18	−0.19
Using monitored natural attenuation rather than active remediation	−0.38	0.74** ($p = 0.005$)
Generating electricity from by-products such as methane gas	0.39	0.08
Social responsibility		
Enhance local employment	0.11	0.09
Bring prosperity to disadvantaged community (increase tax revenue, education, security, etc.)	0.47* ($p = 0.095$)	−0.13
Encourage public participation and stakeholder involvement	0.16	0.37* ($p = 0.087$)
Reducing remediation cost		
Minimize long-term management (e.g. monitoring) requirement	0.20	−0.27
Using fast-track remediation alternative	−0.39	−0.48** ($p = 0.004$)
Reducing life cycle cost	−0.62	−0.27
Increase development value		
Maximize area for redevelopment	−0.38* ($p = 0.098$)	0.08
Reducing site worker's risk	0.00	0.11
Increase property value	−0.49* ($p = 0.064$)	0.13
Sample numbers		

Bootstrapping-based t test results with equality hypothesis rejected at a significance level of 0.1 are denoted by "*", and those at a significance level of 0.01 are denoted by "**", and both are in bold font

Table 4 Test results of divergent stakeholder view—stakeholder influence

	Mean difference Regulator versus primary consultant	Mean difference Primary consultant versus other working parties
Primary stakeholders		
Site owner/manager	0.06	0.17
Regulator	0.82** ($p = 0.006$)	−0.20
Primary consultant	−0.33	0.29
OWP		
Major construction contractor	0.71** ($p = 0.004$)	−0.48* ($p = 0.015$)
Key technology vendor	−0.11	−0.53** ($p = 0.008$)
Sub-tier consultant	0.47* ($p = 0.038$)	−0.46** ($p = 0.009$)
Minor construction contractor	0.30	−0.32* ($p = 0.045$)
Minor technology vendor	0.17	−0.37
Local community		
Local community	0.6* ($p = 0.019$)	−0.09
Environmental groups	0.43	−0.11
Neighboring property owner	0.6** ($p = 0.009$)	−0.27
Media	0.49* ($p = 0.037$)	−0.42* ($p = 0.033$)
Institutional field actor		
Competitors	−0.74** ($p = 0.001$)	0.05
Professional organizations	−0.03	−0.02
Academic	−0.20	−0.27
Intra-organization stakeholders		
Top management of the Organization	−0.51* ($p = 0.081$)	−0.06
Other employees in the Organization	−0.12	0.17

Bootstrapping-based t test results with equality hypothesis rejected at a significance level of 0.1 are denoted by "*", and those at a significance level of 0.01 are denoted by "**", and both are in bold font

stakeholders, and most notably on the influence of regulator (mean difference = 0.82, $p = 0.006$), suggesting that regulators have a strong confidence in their own influences. On the other hand, primary consultant considered competitors and top management of the organization had significantly higher influence than what regulator viewed.

Primary consultant was also compared against OWP, both as private stakeholders, but one as primary stakeholder and one as secondary stakeholder. Table 3 shows that primary consultant gave significantly lower rating than OWP on four sustainable practices (minimizing contaminants left behind, minimizing waste generation, using environmental friendly products, and using fast-track remediation alternative). Primary consultant also gave significantly higher rating than OWP on two sustainable practices: using monitored natural attenuation rather than active remediation, and encouraging public participation and stakeholder involvement. Table 4 shows that primary consultant gave significantly lower rating on stakeholder influence than OWP regarding five types of stakeholders, four of which belong to the category of OWP.

Discussion and conclusions

Divergence in stakeholder views

To what extent stakeholders support sustainable practices depends on how stakeholders perceive such sustainable practices. This study identified the perceptional differences of three primary stakeholders in remediation: site owner, regulator, and primary consultant, as well as other working parities, academia and environmental group. This perceptional divergence may affect stakeholder's decision to support sustainable practices or not. An apparent example is that a stakeholder would not cast strong support if it considers that a certain practice has already been well addressed. The results support the hypothesis that divergent view exists among various types of stakeholders regarding sustainable practices and stakeholder influence. As Table 3 shows, on a number of sustainable practice indicators, different stakeholders had statistically significantly different rating on their adoption. Moreover, Table 4 shows that different stakeholders had significantly different view on the influence of various stakeholders.

Previous studies have found that sustainability considerations exist in different spatial and temporal scales. At the same time, stakeholders also exist at different spatial and institutional scales, which in turn leads to different views and valuation of environmental consequences (Hein et al. 2006). Therefore, it is important to take these into consideration when conducting stakeholder analysis. Stakeholders can have dramatically divergent view on environmental issues and such a divergence can lead to different decisions in project decision making. For instance, in a survey of various stakeholders on the issue of financing carbon capture and storage demonstration project in China, it was found that development banks consider a 5–8 % investment return as being appropriate; while commercial banks consider a 12–20 % investment return as being appropriate. Such a divergence can lead to as much as a 40 % difference in the cost of CO_2 abatement (Reiner and Liang 2011). According to this stakeholder mediating model illustrated in Fig. 1, such a divergent view affects how stakeholders interact in project decision making. Therefore, it is important for policy makers to take this into account when designing policy instruments.

Determinants of stakeholder perception

Align perceived reality with organizational objective

The background, interest, and objective of stakeholders can be conflicting (Frooman 1999; Sullivan et al. 2001). The benefits of sustainable remediation may also accumulate to stakeholders in different ways under various institutional contexts. For instance, site owner can potentially eliminate its liability at lower cost and improve its public image. Regulator may better protect the public by maximizing the net social and environmental benefits. Primary consultant and other working parties can extend their market share and earn profits by providing more specialized professional service. It is natural to postulate that the behavior of a stakeholder depends on its objective. Moreover, the effect of stakeholder's objective is not limited to guiding action, but also the interpretation of the reality. In the present study, there is a general pattern that, when a sustainable behavior aligns with a stakeholder's organizational objective, the corresponding stakeholder, if it has certain decision-making power, would perceive that such a sustainable behavior is better achieved, which may represent a biased view. For instance, site owner, regulator, and primary consultant are all considered primary stakeholders with certain decision-making power. When it comes to long-term and total environmental quality, such as minimizing local scale secondary environmental impact, regulator gave the highest rating among all primary stakeholders. When it comes to avoiding liability, such as reducing local community risk and protecting habitat, site owner gave the highest rating. When it comes to value associated with technical expertise, such as using in situ remediation rather than ex situ remediation and using fast-track remediation alternative, primary consultant gave the highest rating. Such a consistent pattern supports the postulation that stakeholder perception is affected by their organizational objectives.

McDonald suggests that individuals have different outlooks and that can bias the perception of the level of sustainability efforts involved and perception of the amount of difference they make (McDonald and Oates 2006). Involvement is encouraged when actors perceive that their action is instrumental in meeting important needs and goals (Vermeir and Verbeke 2006). The Model of Responsible Environmental Behavior (Hines et al. 1987) suggests that the people's perception of the effect of their own action, termed "Locus of Control", affects their intention to act. People with a strong internal locus of control tend to believe that their actions can make a difference and act more proactively, while people with an external locus of control tend to believe that their actions are insignificant and thus choosing not to act (Kollmuss and Agyeman 2002). The present study suggests that organizations may similarly have an internal locus of control.

It is known that regulator and primary consultant both are deeply involved in decision-making processes. Results in Table 3 indicate that they had statistically significantly divergent view on a number of sustainable considerations. It appears regulator considered these sustainable practices were more effectively adopted than what primary consultant considered: (1) minimizing local scale secondary environmental impacts ($p = 0.012$), (2) using sustainable energy (($p = 0.088$), and (3) bringing prosperity to disadvantaged community ($p = 0.095$). These results are consistent with the postulation as all these three indicators align better with the organizational objective of regulator (i.e. in the public's best interest). On the other hand, Table 3 shows that primary consultant considers these sustainable practices are more effectively adopted than what regulator considers: (1) using in situ remediation rather than ex situ remediation ($p = 0.034$), (2) maximize area for redevelopment ($p = 0.098$), and (3) increase property value ($p = 0.064$). These indicators align better with the objective of primary consultant, which is to use its technical expertise to gain value for its clients. Therefore, the statistically significant results on all six sustainable practices support the postulation that stakeholder perception is mediated by their organizational objective.

The influence of information asymmetry

Stakeholder's perception depends on the information they receive. To interpret the information, it also often needs education or training background in the specific disciplines. It is straightforward that the three primary stakeholders receive more complete information than other stakeholders. In other words, the other stakeholders can potentially have biased views in perceiving the reality due to information asymmetry. As for the three primary stakeholders, site owner would have the most complete information on most issues, but primary consultant would have more complete technical information than site owner, and regulator would have more complete information regarding political will and policy trends. In the present study, it was found that site owner gave relatively high rating for social-responsibility issues, such as enhancing local employment and bringing prosperity to disadvantaged community. This may be due to the fact that site owner is aware of such considerations in the planning phase, while other stakeholders may not be aware of them. Regulator tends to have less first-hand information regarding contaminants left behind. This may help explain why regulator gave higher rating on "minimizing contaminants left behind" than site owner and primary consultant. As for reducing life cycle cost, the ratings were in this order: primary consultant > site owner > regulator. Regulator may have given the lowest rating because they do not really have much cost related information. Site owner had more information about the selected and used remedial alternative; however, they tend to have much less information regarding the remedial alternatives that were not selected. In comparison, primary consultant has more complete information regarding available technology and may know better the challenge in finding more economic solutions, not only because they are closer to this information but also because they have personnel in each discipline (e.g. geology, hydrology, engineering) to best understand the information. On the other hand, this information asymmetry can also lead to an underestimate of remediation cost in the initial planning phase, in which site owner tends to underestimate remediation cost due to lack of information.

Primary consultant has similar organizational objectives as other working parties: to maximize the organization's profit using its technical expertise and gaining value for clients. However, primary consultant has more information available than OWP. Table 3 indicates that primary consultant considered these sustainable practices were more effectively adopted than what OWP considered: (1) using monitored natural attenuation rather than active remediation ($p = 0.005$), and (2) encourage public participation and stakeholder involvement ($p = 0.087$). This is straightforward because both MNA and public participation are usually primarily managed by primary consultant with little involvement from other working parties. Subsequently, many OWP may not be aware of the MNA and public participation operations. This information asymmetry leads to an underestimate of their adoption by OWP. There are also a number of sustainable remediation considerations for which OWP gave higher ratings for: (1) minimizing contaminants left behind ($p = 0.002$), (2) minimizing waste generation ($p = 0.046$), (3) using environmental friendly products ($p = 0.033$), and (4) using fast-track remediation alternative ($p = 0.004$). These differences can also be explained by information asymmetry. On item 1, OWP tend to have less information, if not none, about contamination that is located outside of the treatment zone. Subsequently OWP would know less about residual contaminants after remediation operation, leading to an overly optimistic view. On item 2, it may be due to the fact that OWP know better about their specialized field but know less about other potential concerns at the site, thus having a more optimistic view about waste reduction potential. As information asymmetry can seriously limit the potential of material reuse and waste reduction, this also supports the view that information sharing can be critical for cleaner production initiatives like the circular economy strategy in China (Geng and Doberstein 2008). Moreover, the preservation and continuous use of historical remedial system operation and monitoring data can lead to remediation process optimization that can significantly reduce the cost of remediation (Hou and Leu 2009). On item 3, OWP are usually the parties that purchase the materials used in remediation operation, therefore they may know better than primary consultant that environmental friendly products are being used. As for item 4, similar to the result discussed above regarding MNA, it may simply because OWP are not aware of many other slow-tracked remediation cases.

Stakeholder influence: biased views

All primary stakeholders perceived that they themselves had the highest or near the highest influence on decision making. For instance, site owner rated their own influence to the highest (3.33) and rated most other stakeholder's influence to be <3. Regulator rated their influence to be the highest and primary consultant rated their influence to be the second highest among all stakeholders. OWP put a relatively low rating for their own influence compared to what they gave to the primary stakeholders; however, compared to ratings given by the primary stakeholders, their own ratings were all relatively high. AEG similarly gave a high rating (3.38) as for stakeholder influence by the academic. Overall, it appears evident that all surveyed stakeholders tended to give higher ratings for their own influence. Randomization-based hypothesis testing results also indicate that regulator gave higher ratings than primary consultant as for regulator's influence ($p = 0.006$); and OWP gave higher ratings than primary consultant on four of five types of stakeholders: major construction contractor ($p = 0.015$), key technology vendor

($p = 0.008$), sub-tier consultant ($p = 0.009$), and minor construction contractor ($p = 0.045$). This mechanism, while producing biased views, maybe a good thing for stakeholder involvement. As Fig. 1 shows, the stakeholder perception mediating model suggests that a stakeholder tends to take more action if they perceive that their action has a high impact on project decision making. As more involvement certainly leads to more influence. This mechanism may help create a positive feedback in the stakeholder involvement processes.

Implications

Transdisciplinary research goes beyond collaboration among academic researchers from various disciplines, drawing attention to collaboration between researchers and people affected by the research. The purpose of such collaboration is to generate knowledge that is relevant to practice and helpful to practitioners. In the present study, interactive communication between the researcher and practitioners were conducted. The questionnaire survey and qualitative interview with a wide variety of stakeholders not only generated scientific knowledge regarding sustainability policy, sustainable behavior, and technology usage (Hou et al. 2014a, b, c), but also identified a number of areas for further research. These research areas are listed in Table 5. Some of these responses are related to the practical meaning of sustainability and technological development, and some of them are regarding how to guide action in practice. In general, it appears that practitioners need a lot more support from the research community to be confident about whether their action is sustainable and how to make their action sustainable. Besides soliciting input from the stakeholders into academic research, the researcher also intended to provide feedback to industrial practitioners. The survey results were sent back to the survey participants directly, and also presented on various platforms, including journals and international conferences. The effect of this researcher-to-practitioner feedback is unknown; however, it is considered an important part of this research and the researcher plans to further evaluate and engage in this effort.

One important finding of this study is that stakeholders tend to be optimistic about the issues that align the best with their organizational goals. This may reflect an overly optimism that can be detrimental in promoting sustainable practices. For instance, policy makers focusing on recycling may pay less attention to potential adverse effects from a life cycle and global perspective (Hou et al. 2012a). Studies on environmental behavior have indicated that perceived control can be negatively associated with environmentally appropriate behavior (Grob 1995). This is because overly optimistic people tend to take less actions, or reversely people perceiving a lower control are in general more concerned about environmental processes thus adapting their behavior accordingly. In the context of this study, the implication of this mechanism is that stakeholders may be overly optimistic about the status toward achieving their organizational goals, thus under-investing in the sustainable practices that are actually most critical to their interest. More empirical research is needed to assess the significance of this effect, and more theoretical research can be conducted to derive its implication to the effectiveness of policy instruments. A similar mechanism operates in determining stakeholder's perceived influence: stakeholders tend to view themselves as being influential. While this may represent a distorted view, it is expected to cast a positive feedback loop in stakeholder interaction. As a stakeholder view itself being influential, it is more likely to be proactive in stakeholder engagement; subsequently it will indeed be more influential due to the enhanced engagement; and subsequently it could view itself being further influential.

The present study also found that access to information is a key determinant of stakeholder perception. The implication of this finding is multifaceted. First of all, it implies that access to information affects stakeholder attitude to sustainable practices due to different perception. Secondly, it suggests that information sharing is critical for reaching stakeholder consensus. When stakeholders agree on the status of certain sustainability issue, they are more likely to work together in solving it. Thirdly, it implies opportunities for enhanced sustainable practice by enhanced information sharing. This is not only regarding the capability of obtaining information, but also the willingness and capability of supplying information. For instance, specialized contractor in a remediation project may see unique opportunities in reducing or reusing certain waste stream based on the contractor's special experience and expertise. However, there may simply be no incentive that encourages the contractor to speak out. Enhanced information sharing and stakeholder engagement can materialize such optimization opportunities which may otherwise be missed. However, it should be noted that information access and organizational objective are two different determinants; therefore, it is likely that they may cause changes in two different directions, e.g. information asymmetry weakens sustainable behavior while organizational objective strengthens sustainable behavior. In summary, both factors need to be addressed when designing intervention mechanisms to enhance sustainable practices.

The present study offers a first attempt to identify divergent stakeholder views, their underlying mechanisms, and their potential influence on decision-making processes in adopting sustainable practices in the remediation field. It has a number of limitations. Firstly, the study is limited to a relatively small number of remediation practitioners, which does not necessarily represent the wider remediation

Table 5 Future "sustainable remediation" research suggested by remediation practitioners

Stakeholder/Discipline (experience)	Suggestions
Regulator/Geology (>20 years experience)	Sustainable remediation techniques are not always the cheapest (or quickest) so are quickly discounted by some site owners/developers. A greater understanding of the benefits across the sector and improved relations would advance the future situations
Regulator/Hydrogeochemistry (>20 years experience)	The progress with sustainability agenda is in practical viewpoint very slow. There are pressures not to hamper economic growth and accept solutions that are not environmentally sustainable. It is important to provide proper definition of sustainability and what the regulators can offer
Regulator/Hydrogeology (>20 years experience)	More research needs to be done to draw out general guidelines for choosing remediation technologies without going through life cycle assessment for each project and each site
Contractor/Chemistry (>10 years experience)	There is a vague understanding of what sustainable actually means. More research needs to be done to judge/compare one project's green credentials as to whether it could be done more sustainably or compare it to the sustainability of another project or technique
Contractor/Hydrogeology (>10 years experience)	Since the economic crisis, there has been less investment in the development as well as implementation of new technologies. More technology development is still required to address various challenges
Consultant/Environ. Engineering (>10 years experience)	A common/universal scale needs to be developed for measuring sustainability of remediation projects across the industry, so that various remediation options and projects can be ranked on their sustainability
Consultant/Biology (>15 years experience)	Academic education is a key. Upcoming academic training must not only understand sustainability in concept, but also understand sustainability in real-world applications, as well as various stakeholders views
Consultant/Chemistry (>35 years experience)	The survey should be conducted periodically (yearly) to see how attitudes change
Consultant/Geotechnics (>30 years experience)	While in situ treatment of groundwater is increasingly used; technologies need to be developed to more successfully treat unsaturated soils, thereby removing the need of excavation, treat, and backfill
Consultant/Geophysics (>30 years experience)	A standard methodology needs to be developed to evaluate how sustainability a remediation project is. If you are to set up your own system, you can prove whether the remediation is sustainable or not, depending on what you want to prove. It would be useful to have a standard, controlled methodology, to do sustainability assessment in a fair way

industry. Moreover, the survey was cross-sectional; therefore, it does tell the temporal change of stakeholder attitude. The measure of perceived sustainable practice and perceived stakeholder influence are also subjective rather than objective. Despite these limitations, however, the present study shed lights on an important topic that was not explored previously and render implications to further research. Future researchers can design more robust survey or experiments to confirm these empirical findings. More theoretical development would then be possible.

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