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Using residents' worries about technology as a way of resolving environmental remediation dilemmas

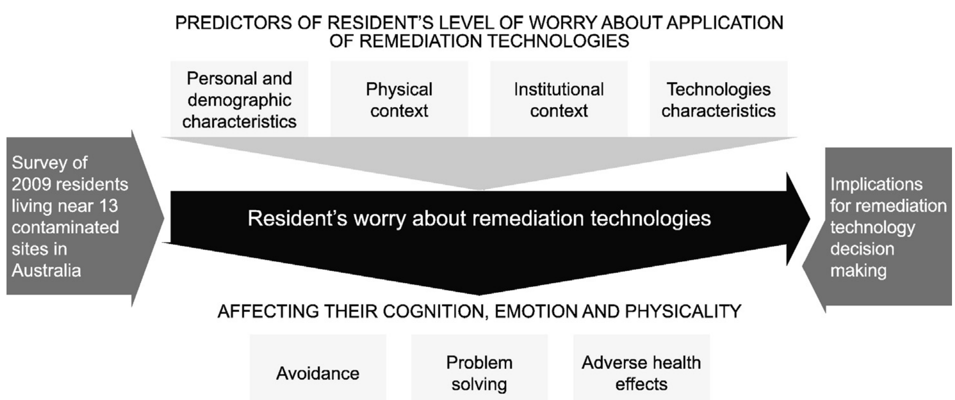
Jason Prior [a,*], Phil Hubbard [b], Tapan Rai [c]

[a] Institute for Sustainable Futures, University of Technology Sydney, Australia
[b] Department of Geography, King's College London, United Kingdom
[c] School of Mathematical and Physical Sciences, University of Technology Sydney, Australia

HIGHLIGHTS

- A framework for understanding residents' worry about remediation technologies
- Builds insights through survey of 2009 residents living near 13 contaminated sites
- Identifies diverse predictors of residents' worry about these technologies
- Reveals how worry about these technologies affects residents' cognition and emotion
- Details how residents' worries can be used to enhance technology decision-making.

GRAPHICAL ABSTRACT



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ABSTRACT

The choice of technologies used to remediate contaminated environments are increasingly made via engagement with affected local residents. Despite this, little is known about how residents perceive remediation technology applications. Building on the findings of broader technology worry research, and drawing on data from a telephone survey of 2009 residents living near thirteen contaminated sites in Australia, regression analysis of closed-ended survey questions and coding analysis of open-ended survey questions are combined to identify the main predictors of worries concerning particular remediation technologies, and how worry affects them. This suggests respondents are more worried about the application of chemical remediation technologies than the application of physical and thermal technologies, which in turn caused more worry than the application of biotechnology. The paper suggests that these worries can be reduced via direct engagement with residents about remediation technologies, suggesting that such engagement can provide knowledge that improves remediation technology decisions.

* Corresponding author.
E-mail address: jason.prior@uts.edu.au (J. Prior).

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1. Introduction

Whilst there remain ongoing debates about whether non-experts should be involved in technology development and application (Collins and Evans, 2007; Evans and Plows, 2007a; Wynne, 2003), over the past few decades there have been important attempts to engage these broader members of society in the application of emergent technologies (Delgado et al., 2011; Pidgeon and Rogers-Hayden, 2007; Priest et al., 2011; Scheufele and Lewenstein, 2005). This shift has been mirrored in the development of more inclusive and participatory approaches to the selection and application of remediation technologies which incorporate the knowledge and experience of a multitude of participants, ranging from government departments, local council planners, through to the residents that may be affected by the remediation of environmental contaminants (Bardos et al., 2011; Benn et al., 2009; Brown and Benn, 2009; Cole, 2011; Forum, 2009; Hillier et al., 2009; National Environment Protection Council, 1999; Pollard, 2004; SuRF-UK, 2009). Whilst these inclusive and participatory approaches necessarily bring residents into highly complex and unfamiliar situations (Gochfeld et al., 2007), research suggests that such processes result in better and more cost-effective decisions about technology (Beierle, 2002; Thomas and David, 2000). As Beierle (2002) notes: "The majority of cases contain evidence of stakeholders improving decisions over the status quo; adding new information, ideas, and analysis; and having adequate access to technical and scientific resources. Indeed, data suggest that it is the more intensive stakeholder processes … that are more likely to result in higher-quality decisions" (p. 739).

Despite these shifts there is an almost complete absence of research that provides insight into how affected residents understand and perceive remediation technologies. The only research that does exist is fragmented and provides tangential insights into particular technologies, preventing a more comprehensive understanding of residents' perceptions of different types of technologies. Accordingly, this article explores how awareness of residents' worries concerning the application of remediation technologies in their local area might improve decision-making. In doing so this articles presents part of the findings of a broader research project exploring residents' worries about the application of different types of remediation technologies in their local area and their acceptance of those technologies. Here, worry provides a particular focus for a number of reasons, including evidence within broader technology perception research that worry is related to, but not correlated with, risk, albeit that that worry is a key mechanism that people use to address risk.

In this paper, 'worry' is understood as a cognitive state (Borkovec et al., 1983; McQueen et al., 2008; Nolen-Hoeksema et al., 2008; Tallis et al., 1994) and as "a chain of thoughts and images, negatively affect-laden and relatively uncontrollable" that "represents an attempt to engage in mental problem-solving on an issue whose outcome is uncertain but contains the possibility of one or more negative outcomes" (Borkovec et al., 1998; Borkovec et al., 1983, p. 10). Worry is also understood as involving an emotional dimension that is related to, although different from, anxiety and stress (Borkovec and Inz, 1990; Davey, 1994; Ferrer et al., 2012; Finucane et al., 2000; Loewenstein et al., 2001; McQueen et al., 2008; Ruscio and Borkovec, 2004; Tallis et al., 1994; Waters, 2008). Worry may also have physiological manifestations that impact on human health and wellbeing (Andrea et al., 2004; Brosschot et al., 2006).

Worry has been described as an important consideration within contemporary 'risk' societies because human beings are future-oriented and uncertainty about the future can potentially come to dominate people's thoughts, emotions and behaviours (Sjöberg, 1998, p. 86). The extent to which people worry about different technological activities in their daily life has been shown to vary, with studies reporting that some technological activities - nuclear power, nuclear waste disposal and energy shortage – can generate significant worry (Burger, 2012; Greenberg and Babcock-Dunning, 2012; McGregor, 1991; Myers et al., 1997), whilst others do not (Alaszewski and Coxon, 2009). Despite this, there is currently an absence of research into residents' worries about the application of remediation technologies, albeit some studies discuss expert anxieties about remediation technologies (Hou et al., 2014; Kato and Davis, 1996; Martin and Ruby, 2004).

This study addresses this current knowledge gap by developing insights into residents' worries concerning the remediation technology applications used to address environmental contaminants in their local area. The study acknowledges that remediation embodies a diverse range of potential technology types that can be used to target specific contaminants in particular ways. Whilst recent remediation technology types such as bioremediation have been the subject of a growing number of studies (Feldman and Hanahan, 1996; Lan Lü, 2009; Vodouhe and Khasa, 2015; Weber et al., 2001), little attention has been paid to the broader range of remediation technology types. Indeed, one significant challenge in exploring how people worry about

Table 1
Remediation technology types (shown in bold) and remediation technology applications (shown in italics) used within the study.

Bioremediation generally refers to the use of biological technologies in the form of microbes, fungi and enzymes to clean up contaminated land and ground water.
- *Microbial bioremediation (insitu)* utilizes microbial activity to remove contaminants in groundwater, waste or soil, and involves delivering something that can stimulate native microorganisms that can degrade contaminants, or a microbial culture to the contaminated medium that is capable of degrading contaminants.
- *Phytoremediation (insitu)* uses plants to clean up contaminated soils and groundwater. This process takes advantage of the ability of plants to take up, accumulate, stabilize and/or degrade contaminants in soil and groundwater.

Thermal remediation generally refers to the use of heat to de-contaminate an area that can be done onsite (in situ) (e.g. steam injection, resistance heating and conductive heating); or carrying out a treatment of excavated soil offsite (ex situ). In particular, thermal treatment is used to treat recalcitrant compounds such as persistent organic pollutants.
- *Thermal desorption (ex-situ onsite)* involves excavating and heating soils so that contaminants are vaporized and the vaporized contaminants are then collected and treated by other means.
- *Incineration (ex-situ offsite)* involves excavating and heating soils so that the contaminants are destroyed. Thermal desorption differs from incineration in that it does not aim to destroy the organic but rather to change the form to a more treatable one.
- *Thermal vapour extraction (in-situ)* involves injecting heat into the soil or waste so that contaminants are vaporized and extracting the vapour that is formed by the heat.

Chemical remediation generally involves the use of chemical reagents to oxidise or reduce contaminants, particularly in groundwater, although the method can extend to soils. There are a number of chemical oxidants that can be used to treat chlorinated solvents, and certain mobile heavy metals.
- *Chemical Treatment general (in-situ)* involves the injection of chemical oxidants or reductants into groundwater or soil, which subsequently leads to the destruction of contaminants of concern or its transformation into something safer.
- *Nanoremediation (in-situ)* involves introducing chemical substances containing microscopic particles called nanoparticles to destroy or degrade the contaminant in the soil or groundwater to an acceptable level.
- *Permeable Reactive Barrier (in-situ)* involves introducing a chemical treatment wall into the groundwater flow, as contaminated groundwater passes through the treatment wall, the contaminants are either trapped by the treatment wall or transformed into harmless substances that flow out of the wall.

Physical remediation generally involves a range of physical techniques such as vacuum extraction (to remove contaminants in vapour form), soil washing, and separation. Excavation and removal of contaminated soil and disposal in a landfill is a very common method of remediation, although the increasing costs of landfill disposal are making this technique less widely used.
- *Encapsulation (in-situ)* comprises the physical isolation and containment of the contaminated material. In this technique, the impacted soils are isolated by low permeability caps, slurry walls, grout curtains, or cut-off walls.
- *Immobilising/stabilization (in-situ, ex-situ)* generally refers to the process that reduces the risk posed by a waste or soil by converting the contaminant into a less soluble, immobile, and less toxic form.
- *Mining (ex-situ onsite, ex-situ offsite)* involves excavation, screening and separation and recycling of all old landfill material. Unusable or contaminant producing materials are then stored.
- *Dig and Dump (ex-situ offsite)* involves the excavation and removal of the contaminated soil from the site and its transporation to a landfill site where it is stored and monitored.

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