


# A geography of residents' worry about the disruptive effects of contaminated sites

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## Abstract

While the links between contaminated sites and adverse effects on human health and well-being are being increasingly recognised, some argue that the magnitude of the health problem is inadequately addressed because it is largely invisible. Health geographies literature has sought to highlight this invisibility by focusing on the link between contaminated sites and health. This study adds to health geographies by presenting unique insights into the geography of residents' worry about the disruptive effect of environmental contamination on health and well-being. It analyses a sample of residents ( $n = 485$ ) living near 13 contaminated sites across Australia. Ordinal logistic regression analysis of closed-format survey questions was combined with coding of open-ended survey questions to reveal the geography of residents' worry about contamination from nearby sites. First, the study explores some of the main relationships between residents, their environs, and contaminants from nearby source sites, which determines their levels of worry: residents' demographics, residents' proximity to sites, contaminant boundaries and borders, and type of contaminant. Second, the study investigates how worry affects residents' health and well-being, ranging from effects on their personal functioning through to their sense of ontological security, which depends in part upon their perceptions of contaminants' impacts. Despite having identified a range of diverse and negative effects of worry about contamination on residents, we found that worry for contamination can also prompt coping strategies and problem-solving, reinforcing the need for more research on this subject.

**Keywords** *health; well-being; contaminated sites; worry; residents; Australia*

## Introduction

'Place matters' to health and well-being (Kearns & Gesler, 1998; Kearns & Moon, 2002, p.610), which is palpable in relation to contaminated sites. Recent estimates suggest that 61 million people are exposed to heavy metals and toxic chemicals from

contaminated sites across the globe (Landrigan *et al.*, 2018, p.18), which have killed tens of thousands of people and injured hundreds of thousands more (Landrigan *et al.*, 2015, p.1429). To redress the exposure to human health risks from these sites, governments and industries are proposing to remediate millions of contaminated sites over

the next few decades across the European Union (European Environment Agency, 2014), the United States (United States Environment Protection Agency, 2016), China (Hou & Li, 2017), and Australia (Carbonell, 2013).

While the links between contaminated sites and adverse effects on human health are increasingly recognised, some argue that the magnitude of the health problem is inadequately addressed because it is *largely invisible* (Landrigan *et al.*, 2015, 2018). Geographers have sought to redress this invisibility. Spanning from medical to health geographies, their work has focused on the effect of environmental contamination on health and well-being. Medical geographers have focused on the biomedical modelling of the effects of environmental contaminants, such as lead and arsenic, on the health of populations, tracing the spread of morbidity and mortality in physical space (Cotter & Patrick, 1981; Eakin *et al.*, 2010; Escamilla *et al.*, 2013; Flörke *et al.*, 2013; Hinchliffe, 2001; Loyd, 2009; Meade, 1976; Scott *et al.*, 2012; Smallman-Raynor & Cliff, 2008; Xu *et al.*, 2006). Health geographers have sought to extend research beyond biomedical modelling (Kearns & Moon, 2002, p.606) by drawing attention to the disruptive effects of environmental contamination and by boosting interest in broader socioecological models of health (Cotter & Patrick, 1981; Cutter, 1995; Few & Tran, 2010; Holifield, 2012; Loyd, 2009; Mansfield, 2012; Sultana, 2012). These models embrace a wide understanding of health that encompasses the concept of well-being and that is associated with 'human flourishing' (Fleuret & Atkinson, 2007, p.109) and 'optimal psychological experience and functioning' (Deci & Ryan, 2008, p.1). On this basis, Kearns and Moon (2002, p.609) contend that 'geographies of health are centrally about the emerging importance of place in the study of health and ... are, in part at least, medical geography's cultural turn'.

Extending health geographies research that explores the effect of contaminated sites, this paper presents findings from a unique study that considers how residents living near contaminated sites worry about environmental contamination from nearby source sites, how their worries impact their health and well-being, and how these worries cannot be discussed apart from lived relationships within their environs. As Sultana (2012) argues in examining 'contaminated citizens' in Bangladesh, contamination cannot be examined as an isolated physical issue. Our study, likewise, explores the geography of residents' worries about

contaminants in their local area, including in relation to perceived disruptions to health and well-being. While previous studies have examined residents' worries about the application of remediation technologies to nearby contaminated sites (Prior *et al.*, 2017), it remains to be determined how and to what extent residents' worry about contamination from nearby industrial, mining, and other sites affects their health and well-being.

Worry is a cognitive state (Hirsch & Mathews, 2012) with an emotional dimension (Ferrer *et al.*, 2012; McQueen *et al.*, 2008). It is constituted by a 'chain of thoughts and images, negatively affect-laden and relatively uncontrollable ... 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.*, 1983, p.10; Prior *et al.*, 2017). Worry has significant implications for general health and well-being, with higher levels of worry linked to direct and indirect negative health and quality of life impacts that may or may not also manifest physiologically (Andrea *et al.*, 2004; Brosschot *et al.*, 2006; Keyes & Simoes, 2012). For instance, worry is a core feature of anxiety, and more likely to become pathological in uncertain situations with potentially negative outcomes, as in the case of environmental contamination (Hirsch & Mathews, 2012). In this study, the focus on worry in the more general form is important. That focus stands in contradiction to considerations of specific disorders or stress-related symptoms insofar as it provides insight into the wider health-related impacts of environmental contamination and fosters a deeper understanding of the relations between the environment and human health and well-being. Having insights into general forms of worry may help prevent more pervasive pathological worry among residents and provide those involved with contamination land management with an understanding of how worry might be engaged with rather than ignored.

Health geographies have increasingly moved towards socioecological approaches to health, with the most recent approaches focusing on human flourishing rather than on physical or mental health per se (Bickerstaff & Walker, 2003; Davis, 2005; Kearns & Moon, 2002; Sultana, 2012). Some such research explores the relations between environmental hazards and worry, and makes interesting contributions to this discipline, conceptualising worry as related to, but distinct from perceived risk, and merging the physical and mental health-related aspects of human flourishing (Kwan, 2012). Furthermore, worry is also an important

consideration in contemporary risk societies, as ‘human beings are future-oriented and uncertainty about the future can negatively affect people’s thoughts, emotions and behaviours’ (Prior *et al.*, 2017, p.883).

The geography of worry presented in this paper derives from the analysis of a survey of residents ( $n = 485$ ) living near 13 contaminated sites across Australia. First, ordinal logistic regression analysis of closed format survey questions is used to identify key determinants of the residents’ worry about contamination from nearby sites. Second, coding of open-ended survey questions provides insights into the effect of worry on their well-being. Third, we outline our conceptual approach for the geography of worry, based on a review of geographical literature at the intersection of contamination and health, and then describe our methods and findings. The paper concludes with a discussion of the findings in the context of the broader literature.

### Conceptualising a geography of worry

The conceptual framework for a geography of worry presented in this section (Figure 1) builds on, and synthesises, a great deal of research into worry and hazards, and draws on prior health geographies research focused on contaminated sites. In conceptualising the geography of worry, we are interested in those factors that affect residents’ levels of worry about the contamination from nearby source sites and also in understanding the focus of their worry and how worry affects their well-being.

As a negative force, worry may have psychological and physiological manifestations that impact on human health and well-being (Andrea *et al.*, 2004; Brosschot *et al.*, 2006), that include adopting a pessimistic outlook or pervasive pathological worry that can lead to fatigue, irritability, muscle tension, or sleeping disturbance (Andrea

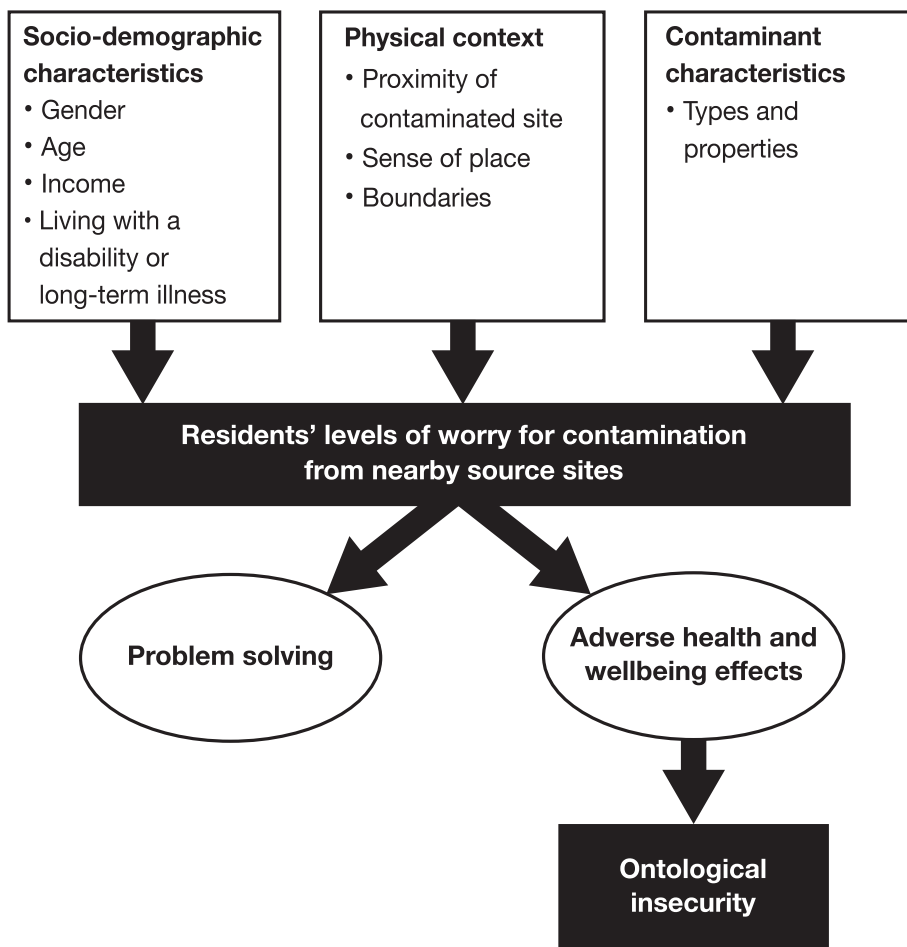


Figure 1 Overview of geography of residents’ worry about contamination from nearby source sites

*et al.*, 2004; Borkovec, 1994; Davey, 1994). We understand that worry can have adverse effects over time, not only affecting a person's physical health, but also their ability to "flourish" (Fleuret & Atkinson, 2007; Stefanovic, 2008). This effect is because a person's well-being—their ability to flourish and optimally operate—and their everyday lifeworld mutually presuppose and afford each other (Malpas, 1999; Stefanovic, 2008). The need for a safe and secure environment for everyday life has been identified as especially important for a person's overall well-being (Charmaz, 1995; Smith, 2012). When our lifeworld—home, place, and local environment—operates without disruption, we are usually unconscious of, or indifferent to it. However, Edelstein (2002) has noted that contamination affects people's "normal" assumptions about life, particularly as they relate to health, personal control, home, and environment. In such ways, the perceived security and safety of a resident's lifeworld can be disrupted, diminishing its ability to accommodate 'human flourishing' (Fleuret & Atkinson, 2007, p.109) or ensure 'optimal psychological experience and functioning' (Deci & Ryan, 2008, p.1). Central to a resident's diminished well-being is deterioration of ontological security, which is 'the confidence that most human beings have in the continuity of their self-identity and in the constancy of their social and material environments' (Giddens, 1991, p.92). Ontological security is one's security of being-in-the-world, and provides grounding for one's sense of self and belonging, and, in turn, well-being (Fleuret & Atkinson, 2007).

While research suggests that worry can have a range of negative effects on a person's health and well-being, it is important to note that it can have a positive consequence. Like other forms of anticipatory cognition, worry can play a critical role in adaptive decision-making, with an appraisal of impending negative thought or danger allowing inner preparation for a subsequent threat or danger stimulus (Bechara *et al.*, 1997; Peters *et al.*, 2006; Tallis *et al.*, 1994, p.62; Waters, 2008, p. 581). As MacGregor (1991, p.321) has suggested, 'we master or make controllable [*risks*] because we invest a great deal of worry in them'.

In this framework, a broad range of factors shape residents' levels of worry. The first of these factors relates to residents' socio-demographic characteristics, the next relates to their physical context, and the last relates to the contaminant types themselves. The attributes constituting each factor are outlined in the next discussion. While these attributes are identified on the basis of

existing research, the study reported here involved a mixed methodology to ascertain whether these or other attributes have a strong effect on residents' worries about the impact of contaminants from nearby source sites.

### *Socio-demographic characteristics*

Researchers have increasingly recognised that the effects of environmental contamination on health are inequitably distributed, disproportionately affecting people on the basis of factors such as gender (Cutter, 1995; Mansfield, 2012; Sultana, 2009, 2012), socio-economic status (Cotter & Patrick, 1981; Darley, 1994; Few & Tran, 2010), and vulnerability (Few & Tran, 2010). Furthermore, compared with the general population, those living with a disability or chronic illness are more likely to experience negative health and diminished quality of life due to exposure to environmental hazards (Abbott & Porter, 2013; Kelman & Stough, 2015; Kovats & Kristie, 2006; Twigg *et al.*, 2011). Whether this inequitable distribution extends to residents' worry about environmental contaminants remains unknown, although research into worry and related topics such as hazard anxiety suggest it might. Previous studies have revealed that socio-demographic factors—gender, age, and socio-economic status—can determine an individual's worry about remediation of nearby contaminated sites (Prior *et al.*, 2017), and other studies have found that similar factors affect human responses to environmental hazards other than contaminants (Ahmad *et al.*, 2017; Ajibade & McBean, 2014; Blake *et al.*, 2017). Furthermore, Gershon *et al.* (2016) have found that "hazard anxiety" following exposure or increased awareness of hazards was more likely to be found amongst persons with disabilities or long-term illness. Influenced by these studies, our framework proposes that residents' levels of worry about contaminants from nearby source sites are not "evenly" distributed across the population and instead are influenced by their socio-demographic profiles and other personal characteristics.

### *Physical context*

Studies have drawn attention to the role that sense of place plays in residents' perceptions of local contamination (Bickerstaff & Simmons, 2009; Bickerstaff *et al.*, 2006) and have highlighted the point that perceived personal risk is related to proximity to environmental hazard sources (Lindell & Earle, 1983; Lindell & Hwang, 2008;

Severtson & Burt, 2012; Signorino, 2012), suggesting that people generally believe that their risk decreases with distance from a source site. Nevertheless, no studies have examined the ways in which residents' proximity to a contaminated site, or their sense of place, affects their levels of worry about the effects of any given contaminant associated with that site. In our framework "sense of place" is understood as a broad construct that incorporates elements of both place identity (Simmons & Walker, 2004) and place attachment (Bonaiuto *et al.*, 2002, p.636; Wakefield *et al.*, 2001); the connections between local residents and immediate environs via personal and collective memories, histories, meanings, concerns, and local cultures. As opposed to knowledge about a place, sense of place forms over time through psychological investment and repeated encounters that gradually accumulate to provide a sense of self and belonging (Tuan, 1991).

The impact of boundaries demarcating the contaminated and uncontaminated is a common theme in the geographical literature on contamination. These boundaries are both physical (Aiken & Leigh, 1975; Galt, 2008, 2010; Herod, 2011; Hinchliffe *et al.*, 2013; Whittow, 1987) and psychosocial (Crang & Zhang, 2012; Segrott & Doel, 2004), and in some cases overlap (Mansfield, 2012). Discussions about borders extend from physical environmental boundaries (Hinchliffe *et al.*, 2013) to human subjects, particularly vulnerable populations, who are imagined as boundaries between outside environmental contamination and populations (Mansfield, 2012). In turn, these physical and subjective boundaries are represented on maps and plans (Galt, 2008). As Severtson and Vatovec (2012) have noted, images shape what people see in hazard contexts; for example, colours and lines on a map can have substantial impacts on how people see and believe. Influenced by these studies, our framework proposes that residents' levels of worry about contaminants from nearby source sites are affected by the physical and psychosocial boundaries they perceive and can be captured in representational maps demarcating the extent of the contaminant created by organisations involved in remediating contaminated sites.

### *Contaminant characteristics*

Increasingly, studies have revealed that contamination is culturally and socially understood, encompassing people's beliefs and values (Aldred & Jungnickel, 2013; Dosman *et al.*, 2001; Eiser *et al.*, 2007; Freudenburg, 1997; Jewitt, 2011).

An example illustrating this point is Sultana's (2012) study of the social and cultural effects of arsenic as contaminant. Our framework proposes that residents' levels of worry about contaminants are influenced by the types of contamination associated with a nearby source site, the cultural and social stigma attached to those types of contaminant, and other characteristics of those types of contaminant, such as their visibility.

### **Methodology**

Drawing from the framework described above, we have had the following research questions:

RQ1. What are the main factors that determine residents' levels of worry for contamination from nearby source sites?

RQ2. What do residents worry about, and how do their worries about contamination from nearby source sites affect their well-being?

We have addressed those research questions using empirical insights collected in a telephone survey of 485 residents aged 18 years and older living near 13 contaminated sites in New South Wales, South Australia, the Australian Capital Territory, Tasmania, Queensland, and Victoria. Purposive sampling was used to select the sites. Suitable sites were identified through an extensive consultation process with the Australian remediation industry, state environmental protection agencies, and the Australian Land and Ground Water Association.

Each site had a range of recognised environmental contaminants present: heavy metals (lead, cadmium, mercury, and arsenic), hydrocarbons (hydrocarbon compounds derived from petroleum sources, including petrol, diesel, kerosene, and lubricating oils/greases), chlorinated solvents (chlorinated hydrocarbons used in dry cleaning), waste (which can include liquids, solids, and gases), and asbestos. All sites included in the study were in urban areas and varied with regard to type and number of contaminants located at the site and background of the site (for instance, age and history of site). They ranged from small sites, such as petrol stations with short remediation timeframes (for instance, three months), to large sites with multiple industrial uses spanning many decades where remediation will continue over many years.

Reflecting the methodological pluralism in health geographies research (Kearns & Gesler, 1998, p.612; Kearns & Moon, 2002; Kwan, 2012), the study addressed the research questions



using both a regression analysis of closed-format questions and a coding analysis of open-format questions from the survey. Closed-format questions alone were suboptimal for addressing the study's research question: given that there is little to no research examining the geography of residents' worry about contamination, it seemed unlikely that any survey would be capable of establishing in advance the full range of responses that might be given by residents (Irwin & Wynne, 1996; Nisbet & Scheufele, 2007). Hence, while the regression analysis of closed-format questions was designed to provide robust quantitative findings of likely dimensions of residents' geographies of worry, the coding analysis was used to provide a more heterogeneous understanding of those dimensions than the standard closed-format questions allowed (Sturgis & Allum, 2004).

To protect the confidentiality and anonymity of participants and sites, only generic information is provided in the remainder of this paper in accordance with the approval from The University of Technology Sydney Human Research Ethics Committee (reference no. 2015000270).

#### *Survey measures and recruitment*

Participants were randomly selected from a residential telephone database for the neighbourhoods surrounding the 13 contaminates sites. The survey response rate was 19 per cent. A pilot of the survey was conducted with 50 participants randomly selected from the telephone database to refine the study's instruments. The final survey used computer-assisted telephone interviewing software application and was completed between 24 March 2014 and 30 September 2014 by 12 researchers calling residents on weekdays between 15:30 and 20:00. These researchers had both training and experience in conducting computer-assisted telephone interviewing and were briefed on the content of the survey. If calls went unanswered or were diverted to voicemail, up to five further attempts were made to contact each resident. Participants were asked their age at the outset of the survey to determine their eligibility (that is, 18 years and over).

During the survey, participants were provided with a brief outline of a contaminant that had been found at a site near to their place of residence. The description read to them included the type of contaminant (for example, mercury), the location of the contaminant, how the contamination occurred, and how it behaved (for example, groundwater). No potential consequences (for example, health

risks) related to the presence of the contaminant were described, to avoid influencing the responses to the survey. Given the vast range of contaminants within the environment, the study focused on the five aforementioned key types of contaminants within the Australian context including heavy metals, hydrocarbons, chlorinated solvents, waste, and asbestos.

An 11-point Likert scale question was used to rate their degree of worry about the contaminant at the nearby site. Participants were asked 'how worried are you about the contamination at the [site], where 0 is not at all worried, and 10 is extremely worried?' This question was the dependent variable in the regression analysis.

Independent variables for the regression analysis were drawn from responses to survey questions that focused on the participants' socio-demographic characteristics (gender, age, income, educational attainment, and status as living with a long-term disability or with a chronic illness), physical context (proximity of contaminated site, sense of place), and views on types of contaminant (each of these is described in detail in Table 1). In particular, location data in the form of latitude and longitude coordinates for the home of each participant were also collected. Polygons were created for the boundaries of each contamination site using geographic information system software. The minimum Cartesian distance (that is, the minimum distance between participant and contamination site boundary) was calculated between the participant's home and nearby site and, in the regression analysis, was used as a measure of physical proximity between each participant and the contamination site.

Participants were also asked to provide an open-ended response to the question 'What is the first thought or image that comes to mind when you think of the [type] contamination at the [name of site]?' Open-ended responses to this question were used in the study's coding analysis.

#### *Participant characteristics*

Of the 485 participants in the study, 54 per cent ( $n = 269$ ) were female participants, and 46 per cent ( $n = 216$ ) were male participants. The age distribution was 18–89 years. Seven per cent ( $n = 36$ ) were under 35 years of age, 31 per cent ( $n = 148$ ) were aged 35 to 54 years, 62 per cent ( $n = 301$ ) were aged 55 years or more. Most participants ( $n = 402$ , 83%) reported that they did not live with a disability or long-term illness, compared with 16

Table 1 Independent variables for the regression analysis

<p>Socio-demographic characteristic</p> <p>University education: 0/1 dummy if the participant had a university degree.</p> <p>Gender: 0/1 dummy if the participant is male.</p> <p>Age under 35: 0/1 dummy if the participant is under 35.</p> <p>Age 35–54: 0/1 dummy for participants aged 35–54.</p> <p>Age 55+: 0/1 dummy for participants aged 55+.</p> <p>Income unspecified: 0/1 dummy for participants who did not specify income.</p> <p>Income 0 to 40,000: 0/1 dummy for household income between \$0 and \$40,000 p.a.</p> <p>Income 40,000 to 80,000: 0/1 dummy for household income between \$40,000 and \$80,000 p.a.</p> <p>Income 80,000 to 120,000: 0/1 dummy for household income between \$80,000 and \$120,000 p.a.</p> <p>Income 120,000+: 0/1 dummy for household income over \$120,000 p.a.</p> <p>Disability/long-term illness status: 0/1 dummy if disability/long-term illness status was yes.</p> <p>Physical context</p> <p>Proximity to contaminated site: The minimum Cartesian distance (that is, the minimum distance between participant and contamination site boundary) was used as a measure of physical distance between each participant and the contamination site.</p> <p>Sense of place: combined response to the statements “I feel like I belong to the community where I live” and “For me, this is the ideal place to live,” which were found to be highly (0.87) correlated.</p> <p>Contamination type</p> <p>Hydrocarbon: 0/1 dummy if the contaminant discussed with the participant was classified as a hydrocarbon.</p> <p>Heavy metal: 0/1 dummy if the contaminant discussed with the participant was classified as a metal.</p> <p>Chlorinated solvent: 0/1 dummy if the contaminant discussed with the participant was classified as a solvent.</p> <p>Waste: 0/1 dummy if the contaminant discussed with the participant was classified as a waste.</p> <p>Asbestos: 0/1 dummy if the contaminant discussed with the participant was classified as asbestos.</p>
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per cent ( $n = 78$ ) of participants who indicated that they did; five chose not to answer this question.

### Regression analysis

Ordered logistic regression analysis was used to determine the influence of a range of socio-demographic, physical context, and contaminant-related characteristics on participants' levels of worry about contamination from nearby source sites (Table 1). Because the dependent variable (worry) was measured on a Likert scale, it was considered an ordinal variable. SPSS and R software were used to carry out the regression data processing and analysis. We sought correlated variables either by eliminating or by combining duplicate or redundant variables (see Table 1).

### Coding analysis

Coding analysis of the open-ended question was used to elaborate on the determinants identified in the regression analysis and to provide insights into the impact of residents, worry on their well-being. Two researchers coded the data manually, using SPSS to record frequencies of codes, and two cycles were used to identify those codes (Sandelowski *et al.*, 2009, 2012):

1. The 485 responses to the open-ended survey question were coded for “worry” related content (Saldaña, 2013). Just over 50 per cent ( $n = 249$ ) were coded as incorporating some reference to the substantive word “worry+” or synonyms (for example, be worried, worrisome, daunting, perturbing, trying, taxing, troublesome, and unsettling).
2. Elaborative coding and focused coding were then applied to the data. Elaborative coding involves analysing textual data in order to develop the findings of a previous study or stage of study further (Auerbach & Silverstein, 2003; Saldaña, 2013). Here, the aim was to enhance understanding of the findings from the regression analysis. Focused coding was also used to uncover frequently occurring themes on how residents' worry affected their well-being and to identify the focus of their worry.

Where verbatim responses are presented in the section below, participants' basic details are represented in brackets after the verbatim response as follows: gender, age, and interview identification number (for example, female, 45, 2415). These verbatim responses from the coded text were selected based on their information richness.

## Results

The findings from the regression analysis and coding analysis were combined to reveal the overlapping dimensions of the geography of residents' worries about contamination from nearby source sites. The first part of the results addresses the study's first research question by presenting findings on the most salient determinants of residents' levels of worry about contamination from a nearby site. These salient determinants include those identified as significant within the regression analysis (Table 2: the heterogeneity of worry within residential populations, residents' proximity to the site, and the worry effect of contaminant types). The second part of the results addresses the study's second research question and considers how residents' worries about contamination affect their well-being in terms of perceived and experienced disruptions to health and well-being, including adverse effect on their ontological security.

### *Factors determining residents' levels of worry*

*Socio-demographic characteristics.* Participants' levels of worry in relation to the contaminant were unevenly distributed based on a range of socio-demographic characteristics (Table 2). Gender had a significant association with worry, with female participants more likely to worry about contamination than male participants (OR 0.44; 95%

CI 0.31, 0.63;  $P = 0.000$ ). There was no significant effect found between people on lower income and worry, although there was a significant difference amongst the higher income groups. Those with a moderately high income (AU\$80,000 to \$120,000) were significantly more likely to worry about contamination than people on a higher income (over \$120,000) (OR 1.77; 95% CI 1.09, 2.88;  $P = 0.021$ ). The ordinal logistic regression found that people who reported living with a disability or long-term illness were significantly more likely to worry about contamination compared with those that did not report living with a disability or long-term illness (OR 12.49; 95% CI 7.58, 20.58;  $P = 0.000$ ).

*Proximity of contaminated site.* The ordinal logistic regression found that proximity of the contaminated site was a significant influence on participants' worry; those who lived closer to a contaminated site were more likely to worry about contamination than those who lived further away (OR 1.36; 95% CI 1.03, 1.80;  $P = 0.031$ ) (Table 2). This association between increased levels of worry and proximity to a contaminated site was reflected in participants worried about how adverse effects to health were amplified by proximity to the source site of the contamination (31%, 76 of 249). As participants noted, 'Very unsafe and unhealthy for people living close' (female, 40, 3220),

Table 2 Ordered logistic regression determining the likelihood of worry about contamination

	Coefficient estimate	SE	<i>t</i> value	OR	95% CI	P value
Age						
55+	0.05	0.203	0.245	1.05	0.71, 1.56	0.806
Under 35	0.147	0.341	0.431	1.16	0.59, 2.26	0.666
Gender: male	-0.815	0.178	-4.577	0.44	0.31, 0.63	0.000*
Income						
0 to 40,000	0.328	0.304	1.077	1.39	0.76, 2.52	0.282
40,000 to 80,000	0.183	0.247	0.740	1.20	0.74, 1.95	0.459
80,000 to 120,000	0.572	0.248	2.304	1.77	1.09, 2.88	0.021*
Unspecified	0.715	0.305	2.341	2.04	1.12, 3.72	0.019*
University education	-0.01	0.189	-0.055	0.99	0.68, 1.44	0.956
Disability/long-term illness status	2.525	0.255	9.915	12.49	7.58, 20.58	0.000*
Proximity to contamination site	0.308	0.143	2.154	1.36	1.03, 1.80	0.031*
Sense of place	0.084	0.047	1.789	1.09	0.99, 1.19	0.074
Contamination type						
Hydrocarbon	0.830	0.232	3.581	2.29	1.46, 3.60	0.000*
Heavy metal	1.044	0.27	3.860	2.84	1.67, 4.83	0.000*
Chlorinated solvent	1.345	0.305	4.413	3.84	2.11, 6.98	0.000*
Waste	0.186	0.313	0.594	1.2	0.65, 2.22	0.552

SE, standard error; OR, odds ratio; CI, confidence interval.

\*  $P < 0.05$  is significant.



‘Cancer problems that arise living close to the site’ (female, 66, 3332), and ‘The closer you live to it, the more the chance of getting something’ (female, 80, 7001).

*Boundaries.* Participants explained that they had higher levels of worry about the perceived health risks of contamination in the nearby environment for certain socio-demographic groups compared with others. Pregnant women and children were understood by participants as being more likely than others to be vulnerable to the perceived health effects of contaminants (female, 35, 7005). For participants, the vulnerability of pregnant women and children positioned them as a front line and a human boundary between the broader population and the health risks associated with the contaminant. For example, as one participant noted, ‘There may just be a little bit of contamination, but a little builds up and then you pass that onto your [unborn] children’ (female, 75, 7009).

The levels of worry that participants had in relation to the possible impact of a contaminant on the health and well-being of residents at six of the 13 sites correlated with the presence of exclusion zones put in place around contaminated sites by state and territory environment protection authorities and then mapped. For participants living near the sites, exclusion zones established observable boundaries that amplified worry about disruptions to health and well-being in given zones and reduced worry outside zones, including in relation to community and property values.

*Contaminant characteristics.* Three contaminant types were found to significantly influence worry; the presence of hydrocarbon, metal, and chlorinated solvent was more likely to cause worry about contamination than asbestos (Table 2). Higher levels of worry associated with hydrocarbon, metal, and chlorinated solvents resulted from their invisibility and the uncertainty this generated for participants about the presence of these contaminants. As one participant explained, a contaminants invisibility ‘raises worry ... you’re never going to know if it’s treated property because—have you got it all, how will we know ... Whereas [if its] visible, you can pick it up and take it away and put it in a cell and you know all of that’s gone’ (female, 55, 7002).

Asbestos was associated with lower levels of worry, which participants explained was because greater media attention and public health awareness raising campaigns focusing on asbestos resulted in people feeling more confident in

knowing what to do in the event of asbestos contamination. As one participant explained,

There was a whole lot of stuff on the media about that asbestos. People were concerned about asbestos, you know, old buildings. But ... people are much more aware [of asbestos] these days. I think, at least we know how to handle that now. You know that if you find asbestos in your home, that you call someone ... People are much more educated these days. (female, 45, 7003)

#### *The focus and experience of residents’ worry*

Participants’ worries were strongly focused on how contamination from nearby source sites might disrupt their own health and well-being and that of other residents (63%, 156 of 249). This worry focused on contaminants’ perceived potential to amplify incidents of mortality and morbidity, for example, ‘cancer’ or ‘lung disease’ (female, 58, 3273; female, 68, 3379; female, 63, 266) and increased levels of general ‘illness’ or ‘sickness’ in residents (male, 57, 76; male, 74, 2066). One focus of these worries was the possibility of cognitive impairment of infants and children (male, 70, 400; female, 65, 296). Moving beyond concerns for physical health, residents also held considerable worries about the psychological and lifestyle impacts of contamination (51%, 126 of 249).

Participants also worried about the ways in which contaminants amplified incidents of mortality and disease in flora, fauna, fungi, and bacteria (41%, 103 of 249). As participants noted, ‘I’m worried about [the contaminant] endangering the life of the people and nature ... the health of people, plants, and animals’ (male, 74, 3177), and ‘[I am worried about] all the dead fish and the damage to the surrounding parks’ (female, 83, 226).

Participants worried about the threat that contaminants posed to the security of their homes (53%, 116 of 249). Home in this context refers to the place, including both house and surrounding local environment, where participants lived. Participants’ worries focused on how positive associations of ‘home’ with privacy, protection, security, amenity, and self-identity were destabilised and inverted by the presence of the contamination. Participants reported that awareness of the presence of a contaminant replaced these positive associations with negative ones; ‘home’ becomes a conceivably hostile environment, filled with ‘lurking’ danger (male, 55, 4026).

Household services came to the fore of the participants' worries as sources of uncertain health risks, including water supply or the soil found *in situ* in yards (female, 64, 5045; female, 62, 386). Concern about these uncertain health risks was amplified by the fact that contaminants were often perceived by participants as 'invisible', 'dangerous', and 'uncontrollable' home intruders (female, 61, 8; female, 70, 25; male, 58, 2268). As one participant asserted, 'I'm worried ... the fact that [the contaminant] can come up through the soil and leach into the water table and the air ... make its way into my home ... I feel exposed, unsafe, in danger' (female, 71, 4045).

Furthermore, participants shared with us how their worry had the potential to affect how they used their homes and local environments. As one noted, contamination had the potential to affect 'the places that allowed me to live a happy and healthy life ... turning them into places to worry about, to fear ... transforming them from places of safety to dangerous places' (male, 37, 412). Another said, 'We heard about contamination in the area close to a local school and all the parents were taking their kids out of school because they were so afraid of contaminants' (male, 75, 7003).

The participants also noted how the health risks posed by contaminants' presence threatened the 'home' as a source of financial security, threatening the longer term well-being of residents. As one participant noted, 'People's properties may be devalued due to contamination ... it makes me anxious' (female, 69, 2021).

As can be seen from the commentary above, worry was often manifested by residents, through both curtailing the activities of their everyday life and through worry being linked to potentially debilitating psychological states such as anxiety. As another participant noted, 'Miss it being a great place to walk the dogs' (female, 55, 3167).

Furthermore, some participants (13%, 32 of 249) indicated that their worry about contamination was accompanied by negative, debilitating feelings of fear, tiredness, exhaustion, unhappiness, despondency, violation, and exposure. For some, a feeling was connected with possible bodily contamination. One participant stated, 'Poisons in the air and the food we eat. ... It worries me, I feel exposed and frightened. I'm tired and exhausted from it all' (female, 69, 2186). Another said, 'It makes you feel uneasy when you think it is at a site where people are living it might get into the drinking water ... it scares me' (female, 76, 4176). Others felt a loss of agency; for instance, 'The little creek down at [Road name] Road, I

am worried about that ... But what can I do?' (male, 47, 79). One participant asserted that the contamination was 'dangerous [and] causes insanity' (female, 57, 5264), and another said, 'I feel sad for the dwellers nearby' (female, 65, 2150).

Few participants (6%, 15 out of 249) referred to the ways in which worry about contamination could have a positive effect, motivating or stimulating them to develop an increased awareness of the effects of the contamination and helping them to clarify their thoughts and feelings. One participant stated, 'I'm fairly confident the technology they have will help. I allayed my worries by calling the [company] and looking stuff up on the internet' (female, 78, 5539). Others took action to find information. One said, 'I was worried about it, so I went to the community info day, and found out about it ... It's a shame that it ever happened but they seem to be doing a good job of cleaning it up' (female, 84, 3106). Another asserted that the company 'didn't help ... I tackled my worries by calling the [environment agency] ... Confident it will be disposed of in the right way' (female, 54, 3062).

## Concluding discussion

This paper has developed a geography of residents' worries about the effects of the presence of contaminants in nearby source sites on their own and others' health and well-being. The insights derived from a survey of residents around Australia have drawn attention to how their levels of worry are determined by socio-demographic characteristics and physical contexts, as well as by the contaminants' characteristics. The survey has also provided insights into the health and well-being concerns manifest in the residents' worries, and how such worries adversely affect their well-being. In concluding this paper, we discuss these insights in the context of broader research and finish by highlighting the study's limitations and opportunities for further research.

The levels of worry reported among participants vary according to socio-demographic characteristics, a finding which supports our foundational premise. In this study, women were more likely to worry about contamination in their residential area than men. This finding aligns with research that has found that women are more likely to report being concerned about the environment (McCright & Xiao, 2014) and may be more likely to experience anxiety disorders in which "worry" is reported as a core feature (McLean *et al.*, 2011). Those in the highest income brackets (AU\$80,000–\$120,000)

were found to be more likely to worry about contamination, which aligns with remediation technology research that found residents with that higher income were more likely to worry than others (Prior *et al.*, 2017). The increased levels of worry reported by those living with disability or long-term illness suggest that disability or long-term illness should be considered in addition to other socio-demographic variables such as gender by professionals involved in the development of community engagement strategies associated with the risk management and remediation of contaminated sites (Holifield, 2012; Mansfield, 2012).

Unsurprisingly, our study found that people who lived in close proximity to a contaminated site were more likely to worry about contamination than those who lived further away. This finding about the relationship between worry and proximity aligns with previous studies, which suggest that people generally believe that their risk from an environmental hazard source decreases with distance from the hazard (Lindell & Earle, 1983; Lindell & Hwang, 2008). This point is particularly important in broader studies that use proximity or distance to hazardous releases as a proxy for potential exposure to harm (Brender *et al.*, 2011; Chakraborty *et al.*, 2011; Margai, 2001; Pollock & Vittas, 1995; Stretesky & Lynch, 1999).

In this study, sense of place was not a significant determinant of worry, although we note findings from a previous study reporting that people with a sense of belonging to their community are more likely to worry about contamination remediation technologies (Prior *et al.*, 2017). More work is likely warranted on this aspect of the problem under investigation.

We also found that physical and psychosocial boundaries and mapped zones amplified residents' worries and exacerbate concerns about possible stigmatisation or financial or other penalty (Fleuret & Atkinson, 2007). Vulnerable populations, such as pregnant women and children, were found to be a focus of worry for residents, given that they are perceived as human boundaries for health risk associated with contamination. This finding about vulnerable populations aligns with research by Mansfield (2012, p.969), who highlights how risk spatialises reproductive women as the 'bodily threshold between the contaminated environment and the population'. Exclusion maps of the spread of contamination from a source site were found to mediate residents' levels of worry about health risks, in line with other research that has found that risk communication image features may influence emotions (Dransch *et al.*, 2010; Severtson &

Vatovec, 2012) and that these features—shading or boundary—can have substantial impacts on what participants see and believe (Severtson & Vatovec, 2012). More broadly, the findings align with research on contamination that acknowledges the existence of “stigma” with respect to real estate and property rights (Mundy, 1992; Patchin, 1988, 1991, 1994; Rinaldi, 1991; Wiltshaw, 1998).

Finally, the study found that residents were more likely to worry about hydrocarbon, metal, or solvent, because they were invisible and less well known, and less worried about asbestos because it is visible and known. These insights about factors that amplify worry for contaminant types align with broader research, which has found that invisible and less well-known types of contaminants are more likely to be associated with higher levels of concern and uncertainty amongst members of the public than other forms of contamination, regardless of actual health risk (Dosman *et al.*, 2001; Eiser *et al.*, 2007; Freudenburg, 1997).

Beyond considering the factors that determine residents' levels of worry about contamination, this study provided insights into how health and well-being manifested within residents, worry for contaminants. Residents' worries were strongly focused on how environmental contaminants might disrupt their physical and mental health, and lifestyle, and less focused on how the contaminant might affect the health of flora, fauna, and the broader ecosystem. This hierarchy of focus mirrors that found in recent research into residents' worries about the application of remediation technologies to nearby source sites (Prior *et al.*, 2017).

Furthermore, the study has provided insights into how worry about contaminants from nearby source sites adversely affects the health and well-being of residents. These insights reflect broader research that highlights that higher levels of worry have been linked to a range of direct and indirect negative health and quality of life impacts (Andrea *et al.*, 2004; Brosschot *et al.*, 2006; Keyes & Simoes, 2012). Findings have revealed that as a site of ontological security, the home is adversely affected by contamination, with positive feelings of personal and place-based control being supplanted by a sense of being threatened, and feeling insecurity and doubt. This new uncertainty and danger reduces people's ability to flourish and function and increases worry and the fear of engaging in everyday activities that can lead to bodily contamination. Furthermore, this uncertainty and danger can lead to a perceived lack of control over one's place or location and create

feelings of helplessness, which may lead to psychological distress (Evans, 2003). These findings about the impact of contamination on home align with arguments within critical geographies of home, which point to how positive connotations of home are constructed and can be subverted by negative experiences (Blunt & Dowling, 2006). Home is an unstable site with shifting meanings, and residents' worry about the effects of contamination highlights this instability.

Despite the diverse negative effects on residents, we found that worry for contamination can also prompt coping strategies and problem-solving, reinforcing broader worry research (Davey, 1994; MacGregor, 1991).

While this study provides a cornerstone for understanding the factors that constitute a geography of residents' worries about contamination from nearby source sites, it has limitations. First, findings may be generalisable to the Australian population but not so beyond that context. Second, the open-ended questions within the survey only elicited short verbatim responses, containing just a few words; this constrained our attempt to uncover worry narrative structures. Third, in addition to the potential for closed-format questions to shape or steer responses in a direction, a further consideration is that even when people have little or no understanding of the science they are being asked to evaluate, many will select one of the fixed alternatives offered to them rather than admit ignorance, simply because the formalities and conventions of surveys stipulate possible answers (Sturgis & Smith, 2010).

Future studies may explore relationships between residents' worries, contaminated environments, and long-term health-related outcomes. The impact on mental health and well-being of long-term worry about contamination is currently unknown; more research could seek to determine such longitudinal effects of worry on those living close to contamination sites and to ascertain the impact of such concern on their quality of life. Such research might focus on both the adverse effects of worry and the potential for worry to generate coping and problem-solving strategies (MacGregor, 1991).

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