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1 **Title: Sociodemographic predictors of residents worry about contaminated sites**

2 Submission to: Science of the Total Environment

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12 **Abstract**

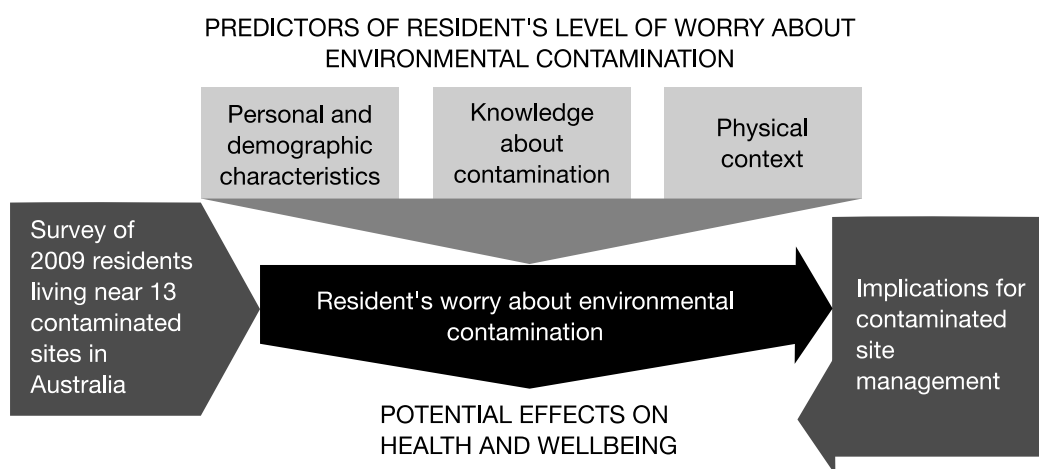
13 The management and remediation of contaminated environments increasingly involves
14 engagement with affected local residents. Of late, risk communication tools and guidelines
15 have drawn attention to the stress and concern of residents as a result of heightened
16 awareness of localised contamination and the need to address these less visible impacts of
17 contamination when engaging with affected communities. Despite this emerging focus,
18 there is an absence of research exploring the factors that predict resident worry about
19 neighbourhood contamination. This paper aims to address this shortcoming by drawing on
20 data from a cross-sectional survey of 2,009 adult residents in neighbourhoods near 13
21 contaminated sites across Australia. Analyses used ordered logistic regression to determine
22 the sociodemographic, environmental, and knowledge-based factors that influence
23 residents' degree of worry. The findings suggest age, gender and income significantly affect
24 residents' degree of worry. Being knowledgeable about the contaminant was associated
25 with lower degrees of worry. Conversely, having a stronger sense of place within a
26 neighbourhood predicted higher degrees of worry. Type of contaminant also impacted
27 resident worry, with residents being less likely to worry about hydrocarbon, asbestos and
28 waste than other types of contaminants. Our analyses suggest resident worry can be

29 reduced through improving access to accurate information and the development of specific
30 risk reduction strategies tailored to each neighbourhood and aimed at the heterogeneous
31 distribution of worry amongst residential populations.

32 **Keywords**

33 Worry, residents, contaminated land and groundwater, policy and practice, engagement

34 **Graphic Abstract**



35

36 **Highlights (max 85 characters for each highlight including spaces):**

- 37
- 38 • Framework for understanding residents' worry about neighbourhood contamination
 - 39 • Details diverse factors, including contaminant types, which affect residents' worry
 - 40 • Provides insights through a survey of 2,009 residents living near 13 contaminated sites
 - 41 • Details how residents' worries can be used to enhance contaminated site management

41 **Acknowledgements**

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43 Environmental Trust. Furthermore, this research has also been funded by the Cooperative
44 Research Centre for Contamination Assessment and Remediation of the Environment (CRC
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46 Technology Sydney and the University of Dundee.

47 **1. Introduction**

48 Environmental contamination in residential communities is widespread and presents
49 significant risks to public health (Fazzo et al., 2017; Norris et al., 2002). Research shows that
50 exposure to acute environmental hazards, such as natural disasters, can have significant
51 effects on mental health, cause significant stress and trauma, and lead to feelings of fear and
52 helplessness (Evans, 2003). In recent years these effects on mental health have been
53 increasingly acknowledged within environmental contamination health policy, as the
54 Australian EnHealth Environmental Health Risk Assessment guidelines state “high levels of
55 stress, concern ... are bound to make the already complex task of risk communication more
56 difficult” (EnHealth, 2012 , p. 88-89). Such policy concerns have been recognised in broader
57 remediation engagement and guidelines acknowledging that ‘heightened stress and anxiety
58 to the point of dread’ may be observed in groups affected by living in or near contaminated
59 sites, (Heath et al., 2010). It has been argued that contaminated site management and
60 remediation approaches need to recognize the value of engaging diverse stakeholder
61 experiences, including those of affected residents, in their efforts to produce more holistic,
62 sustainable approaches to contaminated sites (Cooperative Research Centre for
63 Contamination Assessment and Remediation of the Environment, 2014; EnHealth, 2012 ;
64 National Environment Protection Council, 1999).

65 Residents living near contaminated sites are required to navigate a range of complex issues
66 in their day-to-day lives, such as: having reduced access to neighbourhood spaces, increased
67 costs and inconvenience associated with managing their exposure to contaminants,
68 management of known health problems, prevention of unknown future health problems,
69 litigation processes, communication with government organisations and industry related to
70 the contamination, and impacts from remediation of the contaminated site (Couch and
71 Coles, 2011; Cuthbertson et al., 2016; Peek et al., 2009a; Prior et al., 2017; Shusterman et
72 al., 1991; Takebayashi et al., 2017; Wakefield and Elliott, 2000). Having to manage these
73 issues contributes to existing “daily hassles” (e.g. financial management, traffic, household
74 conflict) leading to stress proliferation (Couch and Coles, 2011), which can manifest as a
75 chronic type of stress (Couch and Coles, 2011) that can increase levels of worry (Zlomke and
76 Jeter, 2014). In the case of neighbourhood contamination, the proliferation of stress can
77 persist for long periods of time, due to the lengthy processes involved in remediation of
78 contaminated sites and a range of complex factors (Couch and Coles, 2011; Matthies et al.,
79 2000; Prior et al., 2017). Consequently, it is critical to have a comprehensive understanding
80 of worry in the context of chronic neighbourhood environmental contamination.

81 Worry is a cognitive state of repetitive thinking related to stress, and a characteristic feature
82 of anxiety (Hirsch and Mathews, 2012; Watkins, 2008). Worry is commonly defined as “a
83 chain of thoughts and images, negatively affect-laden, and relatively uncontrollable”
84 (Brosschot et al., 2006 113). Worry focuses on potential future negative events, and is
85 related to fear, which differs from (although related to) rumination which is a form of
86 repetitive thinking focused on the past (Watkins, 2008; Zoccola and Dickerson, 2012). When
87 it is brief and controllable worry can serve as a constructive process that assists in problem
88 solving and preparation for managing potential threats (Brosschot et al., 2006; Watkins,
89 2008). However, worry is more often studied in the context of being chronic and
90 pathological, as it is involved in most anxiety disorders and associated with depression
91 (McLean et al., 2011; Newman et al., 2013; Watkins, 2008). In this context, worry is
92 considered a problematic perseverative cognition (Brosschot et al., 2006), and is involved in
93 the development and maintenance of generalised anxiety disorder (Newman et al., 2013)
94 and physical health problems such as cardiovascular disease (Brosschot, 2010; Brosschot et
95 al., 2006), and can cause negative effects on the immune system and increase inflammatory
96 responses (Peek et al., 2009b).

97 In the context of chronic environmental contamination, worry is also related to a person’s
98 perceived uncertainty about a potential risk. Having uncertainty about the future is
99 influenced by a perceived lack of knowledge about a situation (Lima, 2004; Powell et al.,
100 2007). Studies have found that residents affected by neighbourhood contamination report
101 worrying (or having “concerns”) about future uncertainty of health impacts, financial
102 security, community acceptance, and remediation technologies (Cuthbertson et al., 2016;
103 Prior et al., 2017; Shusterman et al., 1991; Wakefield and Elliott, 2000). In addition,
104 uncertainty is considered to be an important contributor to psychological stress associated
105 with chronic environmental contamination (Couch and Coles, 2011; Lima, 2004; Matthies et
106 al., 2000).

107 The psychological impact of exposure to chronic technological disasters (human-caused
108 environmental hazards) can be greater than the physical health effects (Cline et al., 2014;
109 Norris et al., 2002). Yet, despite the increasing emphasis on psychological impacts in
110 contaminated site policy, research on the health effects of contamination in residential
111 environments remains primarily focused on direct “objective” risks related to physical and
112 mental health (Brender et al., 2011; Norris et al., 2002; Weems et al., 2018). This comes at
113 the expense of examining the indirect “subjective” mental health and wellbeing of people

114 living in neighbourhoods affected by environmental contamination (Couch and Coles, 2011;
115 Cuthbertson et al., 2016; Norris et al., 2002). Specifically, there is a dearth of research
116 exploring the cognitive factors related to the stress of living with exposure to chronic
117 environmental contamination that influence mental health and wellbeing, such as persistent
118 long-term worry. This paper addresses this significant gap by reporting the results of a study
119 that explored the predictors of resident’s worry about neighbourhood contamination. The
120 study provides insights to help consider how to better integrate the indirect “subjective”
121 psychological experiences of residents into the development of more holistic and
122 sustainable approaches to contaminated site management and remediation.

123 In this paper we present a conceptual framework of worry about neighbourhood
124 contamination. Following this we describe a survey designed to determine the
125 sociodemographic and environmental determinants of a person’s level of worry about
126 contamination in their neighbourhood. The paper concludes with a discussion of the primary
127 factors involved in the development of high amounts of worry about neighbourhood
128 contamination, and the health implications of high levels of chronic worry. Strategies to
129 mitigate this health risk are suggested.

130 **2. A conceptual framework for understanding worry related to neighbourhood** 131 **environmental contamination**

132 Here we present a conceptual framework—developed from the broader literature on worry
133 and perceptions of environmental risk (Auyero and Swistun, 2008; Brosschot, 2010;
134 Brosschot et al., 2006; Powell et al., 2007; Sjoberg, 1998; Vaughan, 1993)—that seeks to
135 explain the primary determinants of residents’ worry about environmental contamination.

136 While worry as a cognitive process can play a positive role in decision-making more
137 generally, it also has the potential to cause significant distress if it is uncontrollable and
138 persistent (Brosschot et al., 2006). Living in a neighbourhood affected by contamination has
139 the potential to cause residents long-term persistent worry related to stress, as the
140 contamination can be present for unknown periods of time and the remediation process can
141 be slow and have unknown consequences (Prior et al., 2017). A consequence of having
142 unknown risks when living near contaminated sites is uncertainty about the future. This may
143 lead to long-term worry causing distress and posing a risk to mental health and wellbeing,
144 even becoming pathological in some cases (Brosschot, 2010). Worry is considered
145 pathological when its severity and duration is disproportionate to what would normally be
146 expected in a specific circumstance (Cuthbertson et al., 2016). Whether or not worry causes

147 psychological stress and develops into more serious mental health problems is dependent
148 on interacting individual psychosocial and environmental factors.

149 The framework developed to inform our study identifies three discrete but interacting
150 dimensions that influence residents' level of worry about neighbourhood contamination.
151 The first dimension in our framework reflects the personal and demographic features that
152 influence resident's level of worry about contamination. For example, females have been
153 found to be more likely to worry about environmental concerns compared to men (Powell et
154 al., 2007), and mothers with children at home may be at greater risk of worry due to
155 concerns about the future health impacts of chronic environmental contamination for their
156 family (Couch and Coles, 2011; Takebayashi et al., 2017). Demographic variables also
157 influence risk perception, which is related to worry, with higher levels of education and
158 financial security associated with less concern about environmental risks (Slimak and Dietz,
159 2006). The literature also suggests that vulnerable populations (e.g. low socioeconomic
160 status, specific cultural groups) may be at risk of higher levels of worry about contamination
161 (Powell et al., 2007), as they experience a greater number of daily stressors leading to
162 greater stress proliferation (Couch and Coles, 2011).

163 The second dimension in our framework constitutes a person's level of knowledge about the
164 contamination in their neighbourhood. A person's perceived lack of knowledge about
165 contamination influences their level of worry about the contamination (Powell et al., 2007).
166 Perceived uncertainty about the future is influenced by a lack of knowledge regarding a
167 specific situation, which can also lead to worry (Powell et al., 2007).

168 Physical context is the third dimension in our framework, which includes contaminant type,
169 tenure of home ownership, physical proximity to the contaminated site, and resident's sense
170 of place within their neighbourhood environment. The concept of sense of place refers to
171 how a specific physical location can have significant strong socially constructed meanings for
172 people developed through familiarity and interaction over time (Venables et al., 2012).
173 Having a sense of place is an important determinant of resilience where there is
174 environmental risk (e.g. contamination) in a neighbourhood (Venables et al., 2012). A
175 number of studies suggest people with a strong sense of place tend to have less concern for
176 potential environmental risks in their area (Venables et al., 2012). Previous studies
177 examining the impact of physical proximity to environmental contaminants suggest that in
178 relation to long-term contamination rather than new developments involving hazardous
179 substances, physical proximity is associated with lower levels of concern and greater

180 acceptance of risk (Burningham and Thrush, 2004; Venables et al., 2012). Home ownership is
181 related to a person's sense of place; people who own their homes may have stronger
182 emotional connections to their neighbourhood, and a greater sense of security and control
183 over their environment that influences their attachment to place (Easthope, 2004; Venables
184 et al., 2012). There is scant research on the relation between worry about environmental
185 contamination and home ownership; however, recent research found no relation between
186 home ownership and worry about contamination remediation (Prior et al., 2017). Finally, the
187 type of environmental contaminant may also be related to worry. Research on
188 contamination remediation strategies has found that the type of contaminant in a
189 neighbourhood environment is a predictor of degree of worry about remediation (Prior et
190 al., 2017).

191 In relation to living with environmental contamination associated with technological hazards
192 there are few published studies exploring the long-term impacts on mental health and
193 wellbeing, or the processes that contribute to psychopathology, such as worry (Cuthbertson
194 et al., 2016; Israel et al., 2006; Ochodo et al., 2014). Consideration of both the subjective
195 and objective dimensions of environmental risk is needed to understand how people make
196 sense of living with environmental contamination and subsequently adapt to such
197 circumstances. Research in this field has demonstrated that perceived health risks are as
198 important as known risks in influencing health and wellbeing (Aldred and Jungnickel, 2013;
199 Alessa et al., 2008; Bickerstaff and Walker, 2003; Davis, 2005; Kushinskaya, 2013; Segrott
200 and Doel, 2004; Slovic et al., 2004).

201 To contribute to the body of research in this area and to address existing gaps in knowledge
202 our study posed the following research question:

203 *RQ. What are the demographic and environmental predictors of resident's level of worry*
204 *about contamination in their neighborhood?*

205 **3. Methods**

206 This was a cross-sectional study that collected survey responses from 2,009 adults (18 years
207 and over) residing near 13 contaminated sites across Australia, in New South Wales, South
208 Australia, the Australian Capital Territory, Tasmania, Queensland and Victoria. A mixed-
209 methods sampling strategy was used which aligned with the research aims. Purposive
210 sampling was used to select the sites. Following site selection probability sampling was used
211 to ensure a representative sample across the sites. Suitable sites were identified through an

212 extensive consultation process with the Australian remediation industry, state
213 environmental protection agencies, and the Australian Land and Ground Water Association.

214 Each site had a range of recognised environmental contaminants present – chlorinated
215 solvents, hydrocarbons, heavy metals, asbestos and putrescible waste. All sites included in
216 the study were located in urban areas and varied with regards to type and number of
217 contaminants located at the site, and background of the site (e.g., age and history of site).
218 These ranged from small sites, such as petrol stations with a short period of history (e.g., 1
219 year) through to large sites with multiple industrial uses spanning many decades where
220 remediation will continue over many years. To protect the confidentiality of survey
221 respondents and sites, only generic information is provided.

222 3.1 Questionnaire and measures

223 A structured questionnaire was deployed to collect the data. Within the questionnaire the
224 respondent was read a brief outline of a contaminant that had been found at a site near to
225 their place of residence. The description provided to residents included: the type of
226 contaminant (e.g., mercury), the location of the contaminant, how the contamination
227 occurred, and how it behaved (e.g., groundwater). No potential consequences (e.g. health
228 risks) related to the presence of the contaminant were described, as this would have
229 influenced the responses to the questionnaire. Given the vast range of contaminants within
230 the environment, the study focused on five key types of contaminants within the Australian
231 context including: heavy metals (i.e. lead, cadmium, mercury and arsenic), hydrocarbons (i.e.
232 hydrocarbon compounds derived from petroleum sources, including petrol, diesel and
233 kerosene and lubricating oils/greases), chlorinated solvents (i.e. chlorinated hydrocarbons
234 used in dry cleaning and industry), waste (i.e. which can include liquids, solids and gases),
235 and asbestos.

236 The respondents were then asked the question “How worried are you about the
237 contamination at the [site]?” with respondents rating their degree of worry on an 11-point
238 Likert type scale, where 0 is *not at all worried*, and 10 is *extremely worried*. Higher values
239 indicate higher levels of worry. This question was used to operationalise the dependent
240 variable “worry” in the regression analysis.

241 The questionnaire also sought information about a range of basic sociodemographic
242 variables, such as gender, age, household income, university education, primary language
243 spoken, home tenure, and number of children living in the home. Each of these variables are

244 described in detail in Appendix 1. Two items were included that reflected a resident's sense
245 of place: "I feel like I belong to the community where I live" and "For me, this is the ideal
246 place to live". Each of these items were measured on an 11-point scale (0 = *strongly disagree*
247 *to 10 = strongly agree*).

248 Location data in the form of latitude and longitude coordinates for the home of each
249 respondent was also collected. Polygons were created for the boundaries of each
250 contamination site using geographic information system (GIS) software. The minimum
251 Cartesian distance (that is, the minimum distance between the respondent's home and the
252 contaminated site boundary) was used as a measure of physical distance between each
253 respondent and the contaminated site. The questions included in the questionnaire were
254 developed as part of a larger study exploring resident perceptions and experiences of
255 contamination and associated remediation technologies (see Prior et al., 2017).

256 3.2 Procedure

257 Ethical approval for this study was provided by the University of Technology Sydney Human
258 Research Ethics Committee. Participants were randomly selected from a residential
259 telephone database for the neighbourhoods surrounding the 13 contaminates sites. The
260 survey was conducted using computer-assisted telephone interviewing (CATI) technologies.
261 The data was collected anonymously with results reported as aggregated data to protect the
262 privacy of participants. The survey response rate was 19%. Surveys were completed
263 between 24 March and 30 September 2014 by a team of 12 researchers who would call
264 residents between Mondays and Thursdays from 15:30 to 20:00. If calls initially went
265 unanswered or were diverted to answering machines, repeat attempts (up to five further
266 occasions) were made to contact each resident. Survey completion time varied from 10 to
267 38 minutes, with an average of 20.4 minutes.

268 3.3 Regression analysis

269 IBM SPSS and R statistical software were used to analyse the data. As the dependant
270 variable worry is ordinal, ordered logistic regression was used to determine the likelihood of
271 a range of sociodemographic, geographic and belief factors on the degree of worry about
272 contamination. The two items "I feel like I belong to the community where I live" and "For
273 me, this is the ideal place to live" were highly correlated ($\alpha = .87$). As there can be no
274 multicollinearity between independent variables in logistic regression (Stoltzfus, 2011),
275 these items were combined to create one variable that reflected the construct sense of

276 place. Continuous variables were recoded into categorical dummy variables prior to entering
277 into the regression model if necessary to ensure linearity of the logit for continuous and
278 ordinal independent variables (Stoltzfus, 2011). See Appendix 1 for detailed descriptions of
279 each variable.

280 The independent variables were chosen for inclusion in the model based on the conceptual
281 framework developed in section 2, which was constructed on feasible predictors found in
282 broader environmental hazards and health research.

283 **4. Results**

284 4.1 Sample characteristics

285 Of the 2,009 respondents, the majority were female (58.5%). The largest age range
286 represented was between 35 and 54 years (28.8%), with those between 18 and 34 being the
287 least represented age range (7.2%). The age distribution was from 18 to 89 years. See Table
288 1 for a summary of the demographic characteristics. Of the 2,009 surveys completed, four
289 were excluded due to data-entry errors at the analysis stage, leaving a total of 2,005
290 respondents.

291

292 **Table 1**

293 Participant sociodemographic characteristics presented as frequencies and percentages.

Characteristic	n (%)
Gender	
Female	1175(58.5) ^a
Male	834 (41.5) ^a
Age range	
Under 35	144 (7.2) ^b
35-54	579(28.8) ^b
55-74	1006 (50.1) ^b
75+	280(13.9) ^b
Income	
Zero to \$40k	377 (18.7) ^c
\$40k to \$80k	405 (20.1) ^c
\$80k to \$120k	361 (18.0) ^c
\$120k and over	460(22.9) ^c
University education (yes)	1153 (57.4) ^d
Children in household (yes)	361 (18.0)
Own or purchasing home (yes)	1652 (82.2)
Language other than English	304 (15.1) ^e

294 Notes: ^a One respondent did not report their gender; ^bOne respondent did not report age; ^c 404
 295 respondents declined to report income, one respondent did not report income; ^d Two
 296 respondents did not report education level; ^e 46 languages other than English were spoken, the
 297 most common being Italian, Greek and French.

298 4.2 Predictors of worry about contamination

299 The results of the ordered logistic regression are shown in Table 2. Males were highly
 300 significantly less likely to be worried about contaminants compared to females (see Gender
 301 [male] in Table 2 and Appendix A). Age had a significant effect on worry about
 302 contamination; with those under 35, and 75 and over being less likely to worry (see Age in
 303 Table 2 and Appendix A). There was also a highly significant effect for household income,
 304 with all income groups being more likely to worry about contamination compared to those
 305 in the highest income bracket (120k +) (see Income in Table 2 and Appendix A). Those who
 306 owned or were purchasing their home were significantly less worried about contamination

307 compared to those who were renting (see Tenure owner or purchasing (yes) in Table 2 and
308 Appendix A).

309 Participants who reported hearing of the contaminant in their suburb were highly
310 significantly less likely to be worried about the contaminant compared to those who had not
311 (see Heard of Contaminant (yes) in Table 2 and Appendix A).

312 Contaminant types were found to have a highly significant effect on the degree to which
313 respondents worry about contamination in their neighbourhood (see Contaminant Type in
314 Table 2 and Appendix A). Respondents were significantly less likely to worry about asbestos,
315 hydrocarbon and waste than they were about metals.

316 Those who spoke a language other than English at home were highly significantly more likely
317 to be worried about contaminants at the site compared to those who did speak English at
318 home (see Language other than English in Table 2 and Appendix A). People with children at
319 home were significantly more likely to be worried about contaminants than those without
320 (see Children in Home in Table 2 and Appendix A).

321 Finally, people identifying as having a sense of place within their community were
322 significantly more likely to worry about contamination in their neighbourhood compared to
323 those without a connection to place (see Sense of Place in Table 2 and Appendix A).

324 **Table 2**

325 Ordered logistic regression coefficients, with the dependent variable being the degree to which
 326 respondents are worried about contaminants at a nearby site. Positive coefficients indicate variables
 327 are associated with higher levels of worry.

Characteristic	Value
Gender (male)	-0.726***
Contamination type	
Waste	-0.565***
Asbestos	-0.894***
Chlorinated solvent	0.064
Hydrocarbon	-0.424***
Metal	0
Tenure own or purchasing (yes)	-0.197*
Language other than English	0.515***
University education	-0.084
Children in household	0.261**
Age	
Under 35	-0.476***
35-54	0
55-74	0.008
75 +	-0.328**
Income	
Unspecified	0.633***
Zero to 40k	0.894***
40k to 80k	0.518***
80k to 120k	0.529***
120K+	0
Heard of contaminant (yes)	-0.29***
Sense of place	0.054**
Distance to site	0.075

328 Note: *** denotes $p < 0.001$; ** denotes $p < 0.01$; * denotes $p < 0.05$.

329 **5. Discussion and conclusion**

330 This paper is the first to develop a conceptual framework seeking to explain the factors
 331 involved in residents' worry about neighbourhood contamination, which was informed by
 332 the broader worry and risk perception literature. This framework provides a first step in
 333 understanding the factors that may lead to pathological worry in the context of a resident
 334 living in an area affected by environmental contamination. This conceptual framework may
 335 be expanded upon through future research. This is also the first study to explore the

336 sociodemographic and environmental factors that affect resident's level of worry about
337 neighbourhood contamination in a large Australian sample. Each of the three dimensions
338 within our conceptual framework contain attributes that our study identified as significant
339 predictors of worry.

340 5.1 Demographic predictors of level of worry about contamination

341 We found a number of demographic variables were significant predictors of residents' level
342 of worry about contamination in their neighborhood; specifically, age, language spoken at
343 home, gender, income, and having children in the household.

344 Consistent with previous research our study found females were more likely to worry about
345 contamination compared to males. An increased level of worry in females may be related to
346 perceived exposure to contamination and environmental risk, as women have consistently
347 been found to have a greater amount of concern about environmental risk compared to
348 men (Davidson and Freudenburg, 1996; McCright and Xiao, 2014; Powell et al., 2007). This
349 finding may partly be explained by women being at greater risk of developing pathological
350 worry (e.g., generalised anxiety disorder) compared to men (McLean et al., 2011). Women
351 are also more likely to worry about health risks more generally compared to men, and
352 health risks have been associated with perceived environmental risk in studies examining
353 resident perceptions of risk associated with living in environments affected by
354 contamination (Couch and Coles, 2011).

355 Both the youngest (<35) and oldest residents were less likely to worry about contamination
356 compared to other age groups in our study. This is consistent with another Australian study
357 finding that older residents (75 and over) were less likely to worry about the remediation of
358 contamination compared to other age groups (Prior et al., 2017). In contrast, the same study
359 found that residents under 35 were also more likely to worry about the remediation of
360 contaminated sites compared to other age groups (Prior et al., 2017). These findings are
361 consistent with the broader literature on age and worry. Older adults are less likely to worry
362 in general compared to other age groups (Gonçalves and Byrne, 2013); however, this can
363 vary depending on the content of their worry. For example, older adults have been found to
364 be more likely to worry about the health and welfare of friends and family (Gonçalves and
365 Byrne, 2013).

366 Consistent with previous research (Cutchin et al., 2008; Cuthbertson et al., 2016), we found
367 that certain demographics related to vulnerable populations predicted worry about

368 contamination. Specifically, people who spoke a language other than English at home were
369 more likely to be worried about contaminants compared to English speakers. This lends
370 support to studies suggesting that the mental health impacts of environmental
371 contamination are greater for certain vulnerable populations, including ethnic minorities
372 (Cuthbertson et al., 2016). In addition, all income groups being more likely to worry about
373 contamination compared to those in the highest income bracket. This indicates that people
374 of a lower socio-economic status may also be more vulnerable to the mental health impacts
375 associated with environmental contamination. (Cuthbertson et al., 2016).

376 Our findings suggest that certain demographic factors may increase a person's risk of
377 pathological worry and need consideration when developing strategies for communicating
378 with residents about contamination. These findings are particularly concerning as people
379 from low socioeconomic backgrounds are at increased risk of anxiety disorders and
380 cardiovascular disease, which both have strong associations with pathological worry
381 (Thurston et al., 2013). Therefore, those on lower incomes, as well as those who speak a
382 language other than English at home, may need additional support to cope with managing
383 environmental contamination in their neighbourhood.

384 5.2 The influence of knowledge on degree of worry about contamination

385 Our study found that residents who reported previously hearing about the contamination in
386 their neighbourhood were less likely to be worried about the contaminant compared to
387 those who had not. This is consistent with the hypothesis that perceived uncertainty about
388 the future is influenced by lack of knowledge about a specific situation, which can also lead
389 to worry (Powell et al., 2007). It is possible that residents who had previous knowledge of
390 the contamination may have had the opportunity to manage their exposure to
391 contamination and have a better understanding of how it might impact them. Consequently,
392 they may have less uncertainty related to the contamination compared to residents who
393 were previously unaware of its presence. It is therefore critical that residents are provided
394 with the information they need about contaminants in their neighbourhood in a timely and
395 accessible manner to reduce unnecessary uncertainty and worry.

396 5.3 Impact of physical context on worry about contamination

397 Certain attributes of residents' physical context appear to influence levels of worry more
398 than others. We found that people who identified as having a strong sense of place within
399 their neighbourhood were more likely to worry about contamination compared to those

400 with a weaker sense of place. This association was also found in another study related to
401 residents worry about contamination remediation technologies (Prior et al., 2017), and is
402 consistent with studies finding that people tend to have less concern about environmental
403 risks in their neighborhood if they have a strong sense of place (Bonaiuto et al., 2016;
404 Venables et al., 2012). In contrast, residents who owned or mortgaged their home were less
405 likely to worry about contamination. These findings are somewhat contradictory as it could
406 be suggested that those who own their own homes would be more likely to have a strong
407 sense of place, as they may perceive a greater sense of security and stability in their living
408 environment (Easthope, 2004).

409 The type of contaminant at the site was also found to be an important predictor of worry,
410 which is consistent with previous research (Prior et al., 2017). However, in our study certain
411 types of contaminants (i.e. waste, asbestos, hydrocarbon) predicted worry about
412 contamination, compared to other types of contaminants (i.e. metal, chlorinated solvents)
413 that did not. It is possible that people may have more knowledge about certain types of
414 contaminants which reduces their uncertainty about contamination risk. However, more
415 research is needed to confirm this assertion.

416 The study revealed that physical proximity to the contaminated site did not influence worry
417 about contamination. Our findings lend support to studies that suggest that proximity tends
418 to be associated with lower levels of worry and greater acceptance of risk (Burningham and
419 Thrush, 2004; Freudenburg and Davidson, 2009). The reasons for this are not fully
420 understood, but one possible explanation is that in the absence of major accidents,
421 increased familiarity by those living closest to a contaminated site leads to lower levels of
422 concern (Greenberg, 2009).

423 5.4 Implications

424 The conceptual framework developed in this paper is significant as it provides a starting
425 point for generating awareness and understanding of how worry is influenced by a range of
426 factors by highlighting the key predictors and categorising them into three primary
427 dimensions. Future research undertaken within this area can build on the framework by
428 exploring whether additional factors feature in impacting upon resident worry levels.

429 Worry has the potential to have a negative impact on health and wellbeing (Cuthbertson et
430 al., 2016), which has previously been described by residents affected by worry about
431 remediation technologies used for contaminated sites using (Prior et al., 2017). Residents of

432 Flint, Michigan reported stress and anxiety they perceived was caused by the unknown
433 health impacts of water contamination in their neighbourhood (Cuthbertson et al., 2016).
434 They also reported stress was increased by concerns about the financial costs associated
435 with the contamination (i.e. access to clean water and health care costs) and perceived
436 inability to control the situation were factors that influenced worry.

437 Within the context of contaminated site management and remediation it is critical that
438 strategies are put in place to assist residents to better manage their worry about
439 contamination. This paper has revealed that levels of worry held by residential populations
440 about contamination from nearby contaminated sites is not evenly distributed amongst
441 those populations due to a range of factors related to demographics, knowledge, and
442 physical context. Awareness of these factors that contribute to worry about contamination
443 are important when developing strategies within the context of contaminated site
444 management and remediation.

445 Strategies and interventions developed on the basis of our findings should include improving
446 access to accurate information to reduce uncertainty related to perceived contamination
447 risk. Having knowledge about health risks can reduce uncertainty about the future (Lima,
448 2004; Powell et al., 2007), better equip people to feel more in control over their situation,
449 and consequently reduce worry. Worry reduction strategies should be developed for
450 residents that are specific to the context of the technological hazard in their neighbourhood.
451 For example, both mindfulness-based training and relaxation training programs have been
452 shown as effective in reducing self-reported worry, anxiety, depression and some
453 physiological symptoms in non-pathological high worriers (Delgado et al., 2010). More
454 research is needed to determine the effectiveness of these type of interventions in residents
455 affected by environmental technological hazards.

456 Personal resilience may be a protective factor that can reduce the negative effects of worry
457 and prevent the onset of mental health disorders (Beesdo et al., 2010). In this context
458 resilience is defined as “the process of adapting well in the face of adversity, trauma,
459 tragedy, threats or significant sources of stress” (American Psychological Association, 2018),
460 and is a critical factor in how people respond to environmental hazard (Cutter, 2008; Foudi
461 et al., 2017). Consequently, it is important to recognise that people have different levels of
462 psychological resilience and ways of coping with environmental hazards due to individual
463 differences (Bonanno et al., 2010), and some people will need more targeted support to
464 manage living with environmental contamination. This paper highlights the varying levels of

465 resilience that residents have to worry about contamination based on a range of factors. For
466 example, our findings suggest that males have significantly lower levels of worry than
467 females. Therefore, strategies aimed at managing and developing individual resilience in
468 addition to community resilience are needed (Liu et al., 2017). This is particularly important
469 for women, as they are more likely to develop anxiety as a consequence of worry (Ryum et
470 al., 2017), and have been found to have a lower level of resilience compared to males in the
471 context of environmental disasters (Rodriguez-Llanes et al., 2013).

472 5.5 Limitations

473 A strength of this study was the large sample size; however, generalisations to the broader
474 Australian population need to be made cautiously. There was a high proportion of home
475 ownership reported in this study (82.2%) compared to the general population (65%;
476 [Australian Bureau of Statistics, 2017](#)); consequently, the responses may not represent all
477 residents affected by contamination. Regional cultural differences may affect the factors
478 that influence worry about contamination; consequently, the findings from this study should
479 be applied cautiously to populations in other regions or countries. Furthermore, in this study
480 worry was not measured using a previously validated tool; however, as argued in this paper,
481 the subjective experience of worry is a critical consideration. There may be other variables
482 that influence worry, such as social capital and ethnicity. These factors have previously been
483 found to influence distress caused by natural disaster (Cuthbertson et al., 2016). Health-
484 related variables may also influence the level of worry experienced by residents. Including
485 these variables may improve the validity of the model; therefore, future research should
486 consider exploring these factors in relation to environmental contamination. In addition,
487 future research should seek to understand resident's self-reported reasons for their level of
488 worry about contamination, as this will assist to identify issues relevant to communities.

489 5.6 Future research

490 Future research could further develop the conceptual framework presented in this paper by
491 identifying additional predictors of worry. Another important area for future research is to
492 determine the individual psychological characteristics (e.g. personality traits and cognitive
493 styles) that influence a person's level of resilience and risk of developing unhealthy "worry"
494 that may lead to poor mental health and wellbeing. Research could seek to characterise
495 those who are more vulnerable to the negative effects of worry related to neighbourhood
496 contamination. Higher levels of worry are associated with certain personality traits, such as
497 neuroticism (Vollrath et al., 1999) and intolerance to uncertainty (Zlomke and Jeter, 2014).

498 Being able to identify people high in these personality traits is important to enable more
499 targeted interventions to support people to manage worry. Longitudinal research is needed
500 to determine the incidence of pathological worry and associated mental health disorders,
501 and whether or not worry about neighbourhood contamination is persistent over time.

502 As we found that people with a primary language other than English were more likely to
503 worry about contamination, future research should consider the impact of ethnicity to
504 determine whether there are additional cultural factors that influence worry in addition to
505 language. Future research also needs to focus on community engagement to support
506 residents to determine the best way to reduce their levels of worry and increase resilience.
507 Adoption of sustainable remediation strategies that encourage public participation may
508 assist to reduce residents worry about contamination, as resident's knowledge of
509 contamination and remediation would increase (Hou and Al-Tabbaa, 2014). Participation in
510 the process is likely to help residents feel more control over the perceived risks. Therefore,
511 future research should aim to develop effective ways of engaging communities in
512 remediation decision-making to facilitate social sustainability in remediation practices (Hou
513 et al., 2014).

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520

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- 686

687 **Appendix 1: Data**

688 ***Independent Variables***

689 **Language other than English (yes):** 0/1 dummy variable, which is 1 if the household speaks a
690 language other than English in the home.

691 **University education:** 0/1 dummy with value 1 if the respondent had a university degree.

692 **Gender:** 0/1 dummy with value 1 if the respondent is male.

693 **Tenure own or purchasing:** 0/1 dummy with value 1 if the respondent owns or is purchasing
694 their home. Other tenures are renting (private), renting (public/social), and other.

695 **Children in household:** 0/1 dummy with value 1 if children younger than 14 are in the
696 household.

697 **Age under 35:** 0/1 dummy with value 1 if the respondent is under 35.

698 **Age 35-54:** 0/1 dummy for respondents aged 25-54.

699 **Age 55-74:** 0/1 dummy for respondents aged 55-74.

700 **Age 75+:** 0/1 dummy for respondents aged 75+.

701 **Income unspecified:** 0/1 dummy for respondents who did not specify income.

702 **Income 0 to 40k:** 0/1 dummy for household income between \$0-\$40k p.a.

703 **Income 40k to 80k:** 0/1 dummy for household income between \$40-\$80k p.a.

704 **Income 80k to 120k:** 0/1 dummy for household income between \$80-\$120k p.a.

705 **Income 120k+:** 0/1 dummy for household income over \$120k p.a.

706 **Sense of place:** A single continuous variable was created by summing the scores of the two
707 items "*I feel like I belong to the community where I live*" and "*For me, this is the ideal place*
708 *to live*". Higher scores reflected having a greater sense of place.

709 **Proximity to contaminated site:** The minimum Cartesian distance (that is, the minimum
710 distance between the respondent's home and contamination site boundary) was used as a
711 measure of physical distance between each respondent and the contamination site.

712 **Heard of contaminant (yes):** 0/1 dummy with value 1 if the respondent had heard of the
713 contaminant in their local area.

714 **Hydrocarbon:** 0/1 dummy with value 1 if the contaminant discussed with the respondent
715 was classified as a hydrocarbon.

716 **Heavy Metal:** 0/1 dummy with value 1 if the contaminant discussed with the respondent
717 was classified as a metal.

718 **Chlorinated solvent:** 0/1 dummy with value 1 if the contaminant discussed with the
719 respondent was classified as a solvent.

720 **Waste:** 0/1 dummy with value 1 if the contaminant discussed with the respondent was
721 classified as a waste.

722 **Asbestos:** 0/1 dummy with value 1 if the contaminant discussed with the respondent was
723 classified as a waste.

724