Uncertainty about the risks associated with microplastics among lay and topic-experienced respondents

Thiele, Christina J.* and Hudson, Malcolm D.

Centre for Environmental Science, Faculty of Environment and Life Sciences, University of Southampton, University Road, Southampton SO17 1BJ, UK

*corresponding author

Email addresses: c.j.thiele@soton.ac.uk and mdh@soton.ac.uk

Abstract

Microplastics are contaminants of emerging concern but there is currently a lack of evidence on actual risks relating to them, despite claims in media and scientific articles. Research on people's perceptions on microplastics is in its infancy. Here we present part of a larger survey about people's perceptions of issues with microplastics. Our analysis of 1681 responses across the globe to an online questionnaire demonstrates a certain level of uncertainty, not only in lay people but also respondents who study/work on the topic of plastics and microplastics as a pollutant. This uncertainty ranges from level of concern about microplastics as an environmental issue to existing evidence for effects. Further, there is some discrepancy between risk perception and state of the research. Some of this may be driven by scientific work with some serious limitations in reporting and methods. This highlights the need for fact-checking of circulating information about microplastics, but also for addressing the discordance between ecotoxicological risk and how risk is framed within the scientific community.

Keywords

Microplastics; uncertainty; risk perception; human health; online survey

Introduction

The study of microplastics as a contaminant is a relatively new research area[1]. Adverse effects caused by microplastics have been shown in laboratory exposure studies on marine organisms– usually derived with microplastic concentrations currently above environmental relevance[2,3]. Projected increases of environmental concentrations towards the next century may lead to detection of ecological effects in the environment[4,5]. Little is known about potential risks to human health[6]. So far, exposure has been confirmed by the detection of microplastics in human food sources and in the atmosphere. Microplastics have been found in urban air[7] and repeatedly in sea salt, seafood and drinks[8–11]. Ingestion through subsequent evacuation was shown for the first time from human stool samples[12], no research on potential retention, or toxicological or pathological effects exist. Information about inhalation of microplastics is based on studies on factory workers with large exposure to synthetic fibres[7]. In an ecotoxicological context, the risks posed to the environment and organism health are still uncertain and evidence often weak[13,14]. This uncertainty partly derives from disparity between microplastics (types, sizes and characteristics) found in the environment and those used in laboratory studies to assess possible effects[14]. Many potential effects have been extrapolated from macroplastic to microplastic level, especially potential toxicological harm from microplastics' associated chemicals or adhered pollutants (see review by Rist *et al.*[15]). Further uncertainty relates to the robustness of the scientific methods of individual studies. Inadequate sampling, for example, can challenge the informative value of research concerning quantification and trends of microplastic concentrations, but also comparisons between studies[16]— adding to the difficulties in demonstrating any harm to organisms or ecosystems.

Interest into microplastics research goes beyond the scientific community. People are likely to have heard about microplastics through the media, including print and digital press articles, documentaries and environmental non-profit non-governmental organisations' (NGOs) social media

campaigns[17]. Claims by these stakeholders often deviate greatly from the currently existing scientific knowledge about microplastic pollution[13]. Activism campaigns can successfully influence policy, albeit at times using arguments based on weak of or flawed evidence. In 1995 the successful Greenpeace media campaign against the decommissioning of the Brent Spar oil storage facility was based at least partly on flawed data[18,19]. More recently, the microbeads ban in cosmetics[20] was based on campaigns supported by weak evidence[21–23]. In addition to such campaigns, scientific 'papers' or 'reports' are being commissioned and published by NGOs and media outlets, without it being clear whether they have had formal independent peer review (see Boyle and Sheets[24]; Santillo *et al.*[25]).

News reports and scientific publications do not always reflect the scientific findings of microplastics research. Völker *et al.*[26] investigated media article topics from the UK and the US that framed environmental risks. One of the three main uncovered narratives was that microplastics in the human food chain adsorb but also leach harmful chemicals[26]. No distinction had been made between pollutants adhering to particles and chemicals leaching from the internal structure of the particles[26]. Furthermore, "other exposure pathways of these chemicals (e.g., contaminated food) do not play a role as this would change the focus of the storyline" (Völker *et al.* 2019:6[27]). This narrative—humans being the end recipient of microplastics and harmful chemicals—was conveyed in 46% of the articles. A further 14% added potential links between human health and microplastic exposure, linking those occurrences to cancer, hormone disruption and passing the blood/brain or cell barriers[26]. Only 7% of the articles communicated in a factual and neutral manner without speculations or interpretations[26]. Similarly, Hoffmann and Walter[27] assessed how the German media covered the topic of microplastics. Between 2012 and 2017, only one of 15 articles was of 'excellent' journalistic quality based on an assessment tool by the Technical University of Dortmund (medien-doktor.de), with a further four being of 'good' journalistic quality[27]. Such reporting issues have also

been found in scientific publications. Völker *et al.*[26] further assessed scientific publications and found that a hypothetical environmental risk (i.e. surrounded by uncertainty and lack of knowledge) was stated in $^{2}/_{3}$ of the 464 analysed publications, while an actual risk was reported by almost ¼. Interestingly, hypothetical risks were reported by effect studies while monitoring studies often stated a risk[26]. Furthermore, stating of risks was often done without providing relevant evidence but rather referring to presence of microplastics in the environment or their ingestion by organisms in addition to saying that the impacts are unknown[26]. Reasons for such framing issues in scientific publications have been attributed to publication bias and disproportionate increase in scientific studies compared to knowledge generation[5,13].

In the light of misrepresentation of issues relating to microplastics we need to ask ourselves if risk terminology is used appropriately not only by the public but by scientists alike. It seems that even topic-experienced people exhibit a perception bias which may be reflected in poor evaluation of the existing literature, potentially through a flawed understanding of risk. Here we present some preliminary results from a larger global internet survey, quantifying uncertainty in perception for the first time. While most results were informative only for directing our own further research, we believe that the findings presented here will be useful for the scientific community and help explore some of the underlying factors of such misrepresentation and uncertainty. Our research was guided by the following questions: What is the level of concern about microplastics in relation to other environmental issues, what are the reasons for concern about microplastics, how do people perceive the hazardousness of microplastics, and do concern levels and hazardousness perception differ between lay-people and people academically or professionally versed in the topic?

Results

Levels of environmental concern

Respondents rated their level of concern for a list of eight environmental issues (mean concern ±95% CI). Climate change was the most concerning issue for lay respondents and topic-experienced respondents alike. Mean values indicated respondents to be moderately (3) to very (4) concerned on all issues (Fig. 1). Microplastics were ranked fifth by lay respondents (3.4±0.043) and third by experienced respondents (3.7±0.076). Respondents' median level of concern was 'very' for most issues for both groups. The exceptions were global population increase and drought for lay respondents, and drought for topic-experienced respondents, which were all rated as 'moderate' concerns. The proportion of lay people who selected 'don't know' ranged 0.5-2.0% for environmental issues, except for microplastics with 8.3%. Similarly, the proportion of topic-experienced people for this selection ranged 0.0-1.2%, except for microplastics with 3.2%. There was a significant difference in concern rankings between groups ($WTS(1) = 4.94$, $p > 0.05$) and within-group concern ranking ($WTS(7) = 534.72$, $p < 0.001$). Post-hoc exploration of within-group concern ranking differences showed significant differences between most environmental issues (Table 1).

When asked a second time about their concern, but without the context of other environmental issues, lay respondents' mean concern about microplastics in the environment stayed at 3.4±0.042; the number of respondents not being concerned fell from 2.9% to 2.0% and respondents expressing 'don't know' from 8.3 to 7.3%. For topic-experienced respondents, when asked again for their level of concern about microplastics without context of other environmental issues fell from 3.7 to 3.6±0.076; number of respondents not being concerned changed from 0.8% to 0.4% and selecting 'don't know' from 3.2 to 2.4%. Asked about changes in concern level over the last year, most respondents' concern about microplastics had increased in the year prior to the survey (63% of

117 experienced and 59% of lay respondents), with 35% of both groups not having had a change in
118 concern.

119

120 Reasons for concern and perceived hazardousness

121 Respondents were asked about their reasons for concern about microplastics. 'Pollution of the
122 marine environment' was selected most often (93% of experienced and 86% of lay respondents),
123 followed by 'might contaminate food sources' (76% and 64%), 'might enter drinking water sources'
124 (73% vs 61%), 'pollution of land' (55% and 52% respectively) and 'might be inhaled if suspended in
125 the air' (38% and 28% respectively). The perceived hazardousness of microplastics was investigated.
126 Respondents were provided with a list of health implications and asked which ones had been linked
127 to microplastics; between 54-73% of lay respondents and 41-71% of topic-experienced selected
128 'don't know', 18-45% of lay and 11-47% of topic-experienced respondents selected 'true' and 4-9%
129 of lay and 11-19% of topic-experienced respondents selected 'false' (Fig. 2a). Respondents were
130 asked twice about cancer; when asked if microplastics had been linked to cancer (Fig. 2a), 37% of lay
131 and 33% of experienced respondents were affirmative and 57% of lay and 51% of topic-experienced
132 respondents were uncertain. When asked if microplastics had been proven to cause some types of
133 cancer, 31% (lay) and 28% (experienced) confirmed this statement and 64% of lay and 53% of topic-
134 experienced respondents expressed uncertainty (Fig. 2b). Respondent evaluated two additional
135 statements; if microplastics had been found in human food sources and if marine organisms had
136 been shown to consume microplastics (Fig. 2b). Here, uncertainty was low; 11-19% of lay and 3-6%
137 of topic-experienced respondents selected 'don't know'. Less than 1% of all respondents selected
138 'false' (Fig. 2b). For all health implications and other statements, there was a significant between-
139 group difference (Table 2). Post hoc testing revealed that, for the human health implication
140 questions, this was due to significantly more experienced respondents selecting 'false' to all

responses, but also that significantly more lay respondents selected ‘don’t know’ to upsetting the hormonal system (Table 2).

Response consistency (data quality)

On two instances respondents were asked the same question again (concern about microplastics, microplastics and-cancer). For concern about microplastics, 84.9% topic-experienced respondents provided the same answer both times, 13.5% changed up or down one level of the Likert scale, 0.8% changed two levels on the scale. 0.8% (2 respondents) selected ‘don’t know’ for one question and either ‘very’ or ‘moderately concerned’ for the other. When asked about cancer, respondents were first asked if cancer in humans had been linked to microplastics, and later in the survey if microplastics had been proven to cause some types of cancer. 78.5% of topic-experienced respondents provided the same answer both times, 2.4% gave opposing answers (half of which responded that proof existed but no link), 19.1% chose ‘don’t know’ for one and a different answer (true/false) for the other question. Lay respondents’ consistency was as follows; 74.8% did not change their concern about microplastics between questions, 19.2% changed up or down one level of the Likert scale, 2.8% changed two levels and 0.1% said they were very concerned one time, and not concerned the other. 4.5% of lay respondents chose ‘don’t know’ for one and a response between not and very concerned for the other question. When asked about microplastics and cancer, 83.4% of lay respondents did not change their responses between questions, 1.2% gave opposing answers (half of which responded that proof existed but no link) and 15.4% chose ‘don’t know’ for one and a different answer (true/false) for the other question—mainly ‘true’ (11.2%).

The ‘don’t know’ responses regarding cancer were broken down further: 8.4% of lay people who stated uncertainty to microplastics having proven to cause cancer were affirmative that a link

between human cancers and microplastics existed, 2.5% were not. Of lay respondents uncertain if microplastics had been linked to human cancers, 2.8% were affirmative about existing proof that microplastics cause some types of cancer, 1.7% were not. Of topic-experienced people, 8.0% who stated uncertainty to microplastics having proven to cause cancer were affirmative that a link between human cancers and microplastics existed, 2.4% were not. Of the topic-experienced uncertain if microplastics had been linked to human cancers, 2.8% were affirmative about existing proof that microplastics cause some types of cancers 6.0% were not.

Discussion

Levels of concern for environmental issues expressed in this survey are comparable to previous studies. Climate change or marine/coastal pollution are often stated as the most important general environmental and marine issues[28–31]. Interestingly, topic-experienced respondents expressed a greater concern for microplastics than lay respondents. Previously, it was found that scientists usually rate risks from their own area of expertise as lower than the general public[32,33]. For example, lay people perceive ecosystem impacts through climate change as slightly more severe, but trust in experts regarding understanding the risk, and potential control of the risk[34,35]. Further research is needed to elucidate lay people's trust in experts on this matter. This increased concern compared to lay respondents is in disagreement with other experts in their field (e.g. see Koelmans *et al.*[13]). Reasons for concern about microplastics are in line with previous work. The latest Eurobarometer reported that 80-90% of European respondents worry about the environmental impact of microplastics[36]. EC[31] reported in 2017 that respondents are more worried about the impact of plastics on the environment compared to their health (87% vs 74%) and in 2019, 48% of Europeans had heard of microplastics being found in food sources, but only 21% were concerned about it[37].

People seem more uncertain if they should be concerned about microplastics compared to other environmental issues. Also, widespread uncertainty exists surrounding knowledge about microplastics in lay people and topic-experienced respondents alike. Even when asking vaguely (i.e. health problems in humans having been linked to microplastics) rather than asking if proof existed, over half of the respondents stated that they did not know. Uncertainty was much lower for knowledge about marine organisms consuming microplastics and the existence of microplastics in human food sources. Those two pieces of information are well-researched and most often covered by the media[26,38,39].

To a lesser degree compared to respondents expressing uncertainty about existing evidence or links to a suite of effects, almost 1/3 of people—including topic-experienced ones—were affirmative about existing evidence or links. This is despite evidence gathered to date suggesting that no proven health effects for humans from microplastics exist[4–6,13–15]. The statement that was affirmed most among experienced and second-most among lay respondents was the link between microplastics and the upsetting of the hormonal system. Völker *et al.*[26] found that "92.8% of media articles imply that risk of microplastics exist and harmful consequences are highly probable" (p.7)[40]. However, in this specific case the evidence provided to date suggests that the chemicals related to plastics in microplastics exert a negligible effect on human health despite commonly being stated in the press, and also in the scientific literature [5,15,26,41]. There is an ongoing debate about the certainty science can put around this and other risks to date[23,42–45]. Indeed, some chemicals associated with plastic production (e.g. phthalates) are suspected to affect the human endocrine system[46]. Handling macroplastic items, such as wearing PVC gloves, mouthing soft plastic toys or food getting into contact with plastic food packaging increases measurable quantities of phthalates, for example, but the half-life in the human body is short[47]. Mechanisms and effects of microplastics are often conjectured from our vast use of much larger items[15]. Humans do ingest microplastics—an umbrella

214 term for a suit of different polymers with a range of additives likely exhibiting different absorption,
215 desorption and leaking characteristics, but their mass and surface area are likely to be well below
216 that of handled macroplastics. Natural particles, food and water are considered the main route of
217 exposure for such chemicals[41,48]. This is not to say that microplastics do not pose a hypothetical risk,
218 but that the evidence—at current microplastic concentrations—does not support most of the
219 statements we put forward in our survey. Extensive work is still needed to adequately assess actual
220 risks microplastics may pose, and toxicology in general is often uncertain.

221

222 Nonetheless, our results show that there is discord between how people perceive microplastics and
223 what we actually know about them. An entire field of research is devoted to how people perceive
224 risks. Risk perception is based on "people's beliefs, attitudes, judgements and feelings, as well as the
225 wider cultural and social dispositions they adopt towards threats to things that we value" (Pidgeon
226 1998:5[49]) as well historical context of the issue in question[50,51]. People's perception of a potential
227 hazard being seen as a risk may also be based on characteristics of such hazard that experts usually
228 do not use, such as catastrophic potential, threats to future generations, judged controllability and
229 dread; the degree of scientific disagreement may also feed into people's idea of risk[49,52]**.** This can be
230 seen in people's perception of air travel being riskier than car travel despite contrary evidence in
231 general, but especially after memorable events such as terrorist attacks[53,54]. Further influencing
232 factors are: if something is believed not to be natural, when trust in regulatory bodies is lacking,
233 uncertainty exists and the type of emotional response that can be triggered[55]. These deep-rooted
234 psychological mechanisms of risk perception are influenced by 'risk signals'[52] , i.e. "occurrences that
235 suggest to the public that the risk is more serious or difficult to manage than had been previously
236 assumed" (Kasperson and Kasperson 2005:10[56]). Many of these above-mentioned factors and
237 mechanisms may affect people's perception of microplastics and regular media coverage and ever-
238 increasing research output may act as such signal.

239

240 Our work suggests that risk perception of topic-experienced people is not in line with the state of
241 knowledge of the research area, indicating personal bias potentially causing misconceptions in the
242 field of microplastic research. High levels of misconceptions in this research area have been
243 suggested previously [13,15,26], but had not been quantified to date. Völker *et al.*[26] found risk framing of
244 microplastics to be common in the scientific literature, about a quarter of studies present
245 microplastics as an environmental risk. This number increases to almost $^{1}/_{3}$ of studies in the area of
246 environmental monitoring[26]. Such studies are concerned with establishing concentrations of
247 microplastics in the environment and therefore do not directly assess potential risks of this
248 contaminant—only the presence and quantity of the hazard. Koelmans *et al.*[13] suggest that
249 pressures to compete in publishing and obtaining of funding as reasons for microplastics risk framing
250 This may well be true; however, it may simply be that people versed in (micro-)plastic research are
251 driven by their risk perception, rather than the state of knowledge, therefore introducing their
252 personal bias into the field. This is supported by Völker *et al.*[26] who found that authors of scientific
253 studies may not use the concept of risk as (eco)toxicologists would do. It may be that authors of said
254 studies understand microplastics' potential hazardousness as the same as them posing an actual risk
255 to human health based on classical risk assessments.

256

257 The most stated health effect among lay and second-most among experienced respondents was that
258 respiratory problems are linked to microplastics. Interestingly, more people were affirmative about
259 this than there were respondents concerned about microplastics possibly being inhaled if suspended
260 in the air. This is a new avenue of research and not much was known when the survey was
261 conducted. The potential of inhalation of microplastics exists, but harm has only been assessed for
262 factory workers exposed to high levels of synthetic fibres (see reviews by Wright and Kelly[6]; Gasperi
263 *et al.*[7]). Up until July 2018, less than 1% of media articles were dedicated to microplastics in the air[26].

It is, therefore, interesting that such a large proportion of respondents were affirmative about a link between health effects from breathing microplastics, while their concern was relatively low, and begs the question were people obtained this insight. A great proportion of people obtain their environmental information via the internet these days[29,31]. Perceptions like the ones we uncovered about microplastics may have come into existence and publicly manifested, during a time that has seen a shift in social interactions, i.e. the rise of user-generated content online. This is amid rising concern over lack of fact checking on social media and the rise of 'Fake News'. In order to evaluate sources of claims relating to microplastics, outputs by a range of entities that communicate to people, be it mass or social media, internet, government authorities or non-government organisations and other public agencies would need to be assessed. A limited number of conventional news outlets and scientific publications have been scrutinised for their quality of environmental journalism and content[26,27], but quality and covered topics of other sources of environmental information are yet to be evaluated. To advance the field of microplastics research, it is essential that the quality of microplastics journalism and general distribution of knowledge become of better quality. This must also include scientific publications.

There are limitations to our study. One of these is the focusing effect, where questioning people about environmental issues brings those issues to people's minds[57,58]. However, we purposefully provided respondents with a list of different issues, which should help to rank microplastics amongst other environmental concerns. When it came to perceived hazards, the relatively large proportion of indeterminate responses suggests that this effect might not be of concern. Secondly, using the wording 'problems linked to microplastics' when enquiring about human health effects through microplastics was not ideal. However, respondents did seem to understand this more like if evidence for such effects existed, as the detailed analysis of one of the repeatedly asked questions has shown. Further, disseminating a study online likely converges responses from areas of higher internet and

social media penetration. Inherent perils of self-selection exist with online surveys[59]. Through self-selection, our study group is likely to be biased towards respondents interested in the topic[60]. Hartley *et al.*[61], using a similar approach to ours, obtained respondents with comparable demographics. Potts *et al.*[30], using a random sampling strategy on the other hand, also reported relatively high levels of university-educated participants. Also, since we expected elevated levels of postgraduate-educated respondents in the topic-experienced group, it is advantageous that demographics between groups are not too dissimilar. Moreover, 25% of experienced and 16% of lay respondents stated to be vegan, vegetarian or not eating seafood for environmental reasons. This suggests a relatively high level of environmental consciousness amongst respondents. Reliable global statistics are scarce, but veganism and vegetarianism in Germany, for example, was 4% in 2016[62], while 10% of our German participants stated to be vegan or vegetarian. In addition, even in studies without self-selection, is has been found that environmental protection is personally important to people[31]. Responses were relatively similar between different demographic groups (see supplementary information online), suggesting robustness of our results.

Conclusion

There is a great deal of uncertainty surrounding the knowledge about microplastics, but also some discrepancy between risk perception and the state of research. Previously suggested by others and confirmed by our results, there seems to be a personal perception bias in people with professional expertise on the topic. A consequence of this bias is likely the discordance between ecotoxicological risk and how risk is framed in the scientific literature around the effects of microplastics. To fully understand this, it is important to qualitatively scrutinise information about microplastics disseminated by the media and through scientific literature alike.

Data and methods

A survey was designed in English and translated to Spanish, German, Italian, French, Polish, Greek, Croatian, Japanese, Thai, Indonesian, Malay, Portuguese, Chinese and Arabic. Back-translation via Google Translate was performed as an additional check. Survey data were collected via SurveyMonkey (www.surveymonkey.co.uk) and the link distributed via social media (Twitter, Facebook and LinkedIn), and messaged directly to the private and professional networks of the authors. Data collection took place between September 2018 and May 2019. All participants were 18 years or older, informed consent was obtained prior to the start of the survey. The questionnaire was attempted by 2084 people. After data cleansing the final sample consisted of 1681 responses. Questions were closed questions. Responses either had to be chosen from a list of options (depending on the question, either single or multiple answers could be selected), required a response on a Likert scale ('not, slightly, moderately or very concerned') or 'true/false', both with the addition of 'Don't know'[63]. Questions related to awareness, concerns and perceived hazards of microplastics. Alongside the survey questions (see section S.1 in supplementary information online), the following demographic information was collected. While country of residence was initially collected, this is not taken into account here due to unbalanced numbers of responses (available at https://doi.org/10.5258/SOTON/D1379).

- Topic experience. The large response rate of topic-experienced people allowed for in-depth analysis between lay and experienced respondents. This was measured by asking respondents "Do you currently work or have you ever worked on the topic of plastics as an environmental contaminant (e.g. microplastics, plastic pollution, marine debris, effects of microplastics on organisms, etc.)? Or/and Are you or have you been involved in a research project on this topic (e.g. BSc or MSc final year project, PhD project etc.)?" as the last question of the survey. Respondents answering 'no' are defined as lay respondents (n = 1430 and as topic-experienced when answered 'yes' (n = 251).

- 65.3% of lay and 65.7% of topic-experienced respondents were female, 33.5% and 33.1% respectively male, the remainder of respondents opted for 'prefer not to say'.
- Age: 14.3% of lay and 21.5% of experienced respondents were 18-24 years, 64.2% and 65.7% respectively were 25-44 years, 17.2% and 10.8% were 45-64 year, 3.6% and 1.6% were 65 years and above, while 0.7% of lay and 0.4% of experienced respondents did not want to disclose this information.
- Highest level of education completed: 0.3% of lay and 0.4% of experienced respondents did not have any qualifications, 13.4% and 7.6% respectively had completed secondary school or equivalent, 36.4% and 28.7% possessed an undergraduate degree or had completed trade/technical/vocational training, 49.1% and 63.3% respectively possessed a postgraduate degree, while 0.8% of lay respondents did not want to disclose this information.

Statistical analyses were conducted with RStudio 1.0.153[64]. Concern ratings were presented as means ±95% confidence interval (CI; and standard deviation). Between group and within group differences (environmental issues of concern) were set to be analysed using a mixed-design ANOVA. This is a similar approach to Hartley *et al.*[61] who used a series of one-way repeated measures ANOVAs, but accommodates a between-subjects variable. Assumptions were not met for normality (Anderson-Darling test), homogeneity of variances (Levene's test) and sphericity (Mauchly's sphericity test). The 'f1.ld.f1' function (R software package nparLD[65]) was used as a non-parametric equivalent and its Wald-type statistic (WTS) reported[66]. 'Don't know' answers were coded as '0'. Post-hoc testing was performed with a pairwise comparison Wilcoxon signed rank test and Bonferroni correction[67]. Between-group differences for statements relating to reasons for concern about microplastics were assessed with Pearson's chi-squared tests to test for associations (Yates Correction when <5 responses in a category) between answers comparing frequency counts of each possible answer (true, false and don't know)[68]. Post hoc testing was performed with the residuals of

the Pearson's χ^2 using the package 'chisq.posthoc.test'[69]. A Bonferroni correction was applied for multiple χ^2 tests (12 tests for questions), reducing the α-value to 0.004. To assess response consistency, two questions were asked twice: concern level regarding microplastics was questioned twice (once in context of other environmental issues, once on its own) and with reverse scales; and a statement regarding cancer. A percentage distribution result analysis by demographics can be found in the supplementary information section S.2.

References

1. Cole, M., Lindeque, P., Halsband, C. & Galloway, T. S. Microplastics as contaminants in the marine environment: A review. *Mar. Pollut. Bull.* **62**, 2588–2597 (2011).

2. Cunningham, E. M. & Sigwart, J. D. Environmentally accurate microplastic levels and their absence from exposure studies. *Integr. Comp. Biol.* **59**, 1485–1496 (2019).

3. Phuong, N. N. *et al.* Is there any consistency between the microplastics found in the field and those used in laboratory experiments? *Environ. Pollut.* **211**, 111–123 (2016).

4. Everaert, G. *et al.* Risk assessment of microplastics in the ocean: Modelling approach and first conclusions. *Environ. Pollut.* **242**, 1930–1938 (2018).

5. SAPEA. *A scientific perspective on microplastics in nature and society*. (Science Advice for Policy by European Academies (SAPEA), 2019).

6. Wright, S. L. & Kelly, F. J. Plastic and human health: A micro issue? *Environ. Sci. Technol.* **51**, 6634–6647 (2017).

7. Gasperi, J. *et al.* Microplastics in air: Are we breathing it in? *Current Opinion in Environmental Science and Health* vol. 1 1–5 (2018).

8. Li, J., Yang, D., Li, L., Jabeen, K. & Shi, H. Microplastics in commercial bivalves from China. *Environ. Pollut.* **207**, 190–195 (2015).

9. Yang, D. *et al.* Microplastic Pollution in Table Salts from China. *Environ. Sci. Technol.* **49**, 13622–13627 (2015).

10. Kosuth, M., Mason, S. A. & Wattenberg, E. V. Anthropogenic contamination of tap water, beer, and sea salt. *PLoS One* **13**, e0194970 (2018).

11. Schymanski, D., Goldbeck, C., Humpf, H.-U. & Fürst, P. Analysis of microplastics in water by micro-Raman spectroscopy: Release of plastic particles from different packaging into mineral water. *Water Res.* **129**, 154–162 (2018).

12. Schwabl, P. *et al.* Detection of Various Microplastics in Human Stool. *Ann. Intern. Med.* **171**, 453 (2019).

13. Koelmans, A. A. *et al.* Risks of Plastic Debris: Unravelling Fact, Opinion, Perception, and Belief. *Environ. Sci. Technol.* **51**, 11513–11519 (2017).

14. Burns, E. E. & Boxall, A. B. A. Microplastics in the aquatic environment: Evidence for or against adverse impacts and major knowledge gaps. *Environ. Toxicol. Chem.* **37**, 2776–2796 (2018).

15. Rist, S., Carney Almroth, B., Hartmann, N. B. & Karlsson, T. M. A critical perspective on early communications concerning human health aspects of microplastics. *Sci. Total Environ.* **626**, 720–726 (2018).

16. Underwood, A. J., Chapman, M. G. & Browne, M. A. Some problems and practicalities in design and interpretation of samples of microplastic waste. *Anal. Methods* **9**, 1332–1345

(2017).

17. GESAMP. Sources, fate and effects of microplastics in the marine environment: a global assessment. in *Rep. Stud. GESAMP* (ed. Kershaw, P. J.) vol. No. 90 96 (IMO/FAO/UNESCO-IOC/UNIDO/WMO/IAEA/UN/UNEP/UNDP Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection, 2015).

18. Zyglidopoulos, S. C. The social and environmental responsibilities of multinationals: Evidence from the Brent Spar case. in *Journal of Business Ethics* vol. 36 141–151 (2002).

19. Bakir, V. Greenpeace v. Shell: media exploitation and the Social Amplification of Risk Framework (SARF). *J. Risk Res.* **8**, 679–691 (2005).

20. Dauvergne, P. Why is the global governance of plastic failing the oceans? *Glob. Environ. Chang. - Hum. Policy Dimens.* **51**, 22–31 (2018).

21. Murphy, F., Ewins, C., Carbonnier, F. & Quinn, B. Wastewater treatment works (WwTW) as a source of microplastics in the aquatic environment. *Environ. Sci. Technol.* **50**, 5800–5808 (2016).

22. Nelson, D., Sellers, K., Mackenzie, S. & Weinberg, N. Microbeads-a Case Study in How Public Outrage Fueled the Emergence of New Regulations. *Curr. Pollut. REPORTS* **5**, 172–179 (2019).

23. Burton, G. A. Stressor Exposures Determine Risk: So, Why Do Fellow Scientists Continue To Focus on Superficial Microplastics Risk? *Environ. Sci. Technol.* **51**, 13515–13516 (2017).

24. Boyle, S. & Sheets, M. Tiny plastic particles are 'part of the air we breathe' say scientists and can damage lungs, poison kidneys and even interfere with our hormones. *Daily Mail Online* https://www.dailymail.co.uk/news/article-5516159/Plastic-particles-air-supermarket-fish-sample.html (2018).

25. Santillo, D. *et al. Plastic pollution in UK's rivers: a 'snapshot' survey of macro-and microplastic*

contamination in surface waters of 13 river systems across England, Wales, Scotland and Northern Ireland | Technical Report 4-2019. (2019).

26. Völker, C., Kramm, J. & Wagner, M. On the Creation of Risk: Framing of Microplastics Risks in Science and Media. *Glob. Challenges* 1900010 (2019) doi:10.1002/gch2.201900010.

27. Hoffmann, C. & Walter, I. Reporting on Microplastic in the Marine Environment: Does Coverage in German Print Media meet the Standards of Quality Journalism? in *MICRO 2018. Fate and Impact of Microplastics: Knowledge, Actions and Solutions.* (eds. Baztan, J. et al.) 310–311 (MSFS-RBLZ., 2018).

28. Buckley, P. J. *et al.* Ten Thousand Voices on Marine Climate Change in Europe: Different Perceptions among Demographic Groups and Nationalities. *Front. Mar. Sci.* **4**, 206 (2017).

29. Gelcich, S. *et al.* Public awareness, concerns, and priorities about anthropogenic impacts on marine environments. *Proc. Natl. Acad. Sci. U. S. A.* **111**, 15042–7 (2014).

30. Potts, T., Pita, C., O'Higgins, T. & Mee, L. Who cares? European attitudes towards marine and coastal environments. *Mar. Policy* **72**, 59–66 (2016).

31. EC. Attitudes of European citizens towards the environment. *Spec. Eurobarom.* **468**, (2017).

32. Sjöberg, L. The Allegedly Simple Structure of Experts' Risk Perception: An Urban Legend in Risk Research. *Sci. Technol. Hum. Values* **27**, 443–459 (2002).

33. Slimak, M. W. & Dietz, T. Personal values, beliefs, and ecological risk perception. *Risk Anal.* **26**, 1689–1705 (2006).

34. Lazo, J. K., Kinnell, J. C. & Fisher, A. Expert and Layperson Perceptions of Ecosystem Risk. *Risk Anal.* **20**, (2000).

35. Kellstedt, P. M., Zahran, S. & Vedlitz, A. Personal Efficacy, the Information Environment, and

453 Attitudes Toward Global Warming and Climate Change in the United States. *Risk Anal.* **28**,
454 (2008).

455 36. EC. Attitudes of European citizens towards the environment. *Spec. Eurobarom.* **501**, (2020).

456 37. EC. Food safety in the EU. *Spec. Eurobarom.* **EB91.3**, (2019).

457 38. Zhang, Q. *et al.* A Review of Microplastics in Table Salt, Drinking Water, and Air: Direct Human
458 Exposure. *Environ. Sci. Technol.* **54**, 3740–3751 (2020).

459 39. Wright, S. L., Thompson, R. C. & Galloway, T. S. The physical impacts of microplastics on
460 marine organisms: A review. *Environ. Pollut.* **178**, 483–492 (2013).

461 40. Völker, C. *et al.* More Than a Potential Hazard—Approaching Risks from a Social-Ecological
462 Perspective. *Sustainability* **9**, 1039 (2017).

463 41. EFSA. Presence of microplastics and nanoplastics in food, with particular focus on seafood.
464 *EFSA J.* **14**, 4501 (2016).

465 42. Kramm, J., Völker, C. & Wagner, M. Superficial or Substantial: Why Care about Microplastics
466 in the Anthropocene? *Environ. Sci. Technol.* **52**, 3336–3337 (2018).

467 43. Leslie, H. A. & Depledge, M. H. Where is the evidence that human exposure to microplastics is
468 safe? *Environ. Int.* **142**, 105807 (2020).

469 44. Gouin, T. *et al.* Clarifying the absence of evidence regarding human health risks to
470 microplastic particles in drinking-water: High quality robust data wanted. *Environmental*
471 *International* 106141 (2020) doi:10.1016/j.envint.2020.106141.

472 45. Wardman, T., Koelmans, A. A., Whyte, J. & Pahl, S. Communicating the absence of evidence
473 for microplastics risk: Balancing sensation and reflection. *Environmental International* 106116
474 (2020) doi:10.1016/j.envint.2020.106116.

46. Grindler, N. M. *et al.* Exposure to Phthalate, an Endocrine Disrupting Chemical, Alters the First Trimester Placental Methylome and Transcriptome in Women. *Sci. Rep.* **8**, 1–9 (2018).

47. Heudorf, U., Mersch-Sundermann, V. & Angerer, J. Phthalates: Toxicology and exposure. *Int. J. Hyg. Environ. Health* **210**, 623–634 (2007).

48. Hartmann, N. B. *et al.* Microplastics as vectors for environmental contaminants: Exploring sorption, desorption, and transfer to biota. *Integr. Environ. Assess. Manag.* **13**, 488–493 (2017).

49. Pidgeon, N. Risk assessment, risk values and the social science programme: why we do need risk perception research. *Reliab. Eng. Syst. Saf.* **59**, 5–15 (1998).

50. Bickerstaff, K. Risk perception research: socio-cultural perspectives on the public experience of air pollution. *Environ. Int.* **30**, 827–840 (2004).

51. Lidskog, R. In Science We Trust? On the Relation between Scientific Knowledge, Risk Consciousness and Public Trust. *Acta Sociol.* **39**, 31–56 (1996).

52. Slovic, P. Perception of risk. *Science (80-.).* **236**, 280–285 (1987).

53. Carlsson, F., Johansson-Stenman, O. & Martinsson, P. Is transport safety more valuable in the air? *J. Risk Uncertain.* **28**, 147–163 (2004).

54. Ito, H. & Lee, D. Assessing the impact of the September 11 terrorist attacks on U.S. airline demand. *J. Econ. Bus.* **57**, 75–95 (2005).

55. Pidgeon, N. *et al.* Exploring early public responses to geoengineering. *Philos. Trans. R. Soc. A Math. Phys. Eng. Sci.* **370**, 4176–4196 (2012).

56. Kasperson, R. & Kasperson, J. *Social Contours of Risk, 1 : Publics Risk Communication and the Social Amplification of Risk.* (Earthscan, 2005).

57. Schkade, D. A. & Kahneman, D. Does Living in California Make People Happy? A Focusing Illusion in Judgments of Life Satisfaction. *Psychol. Sci.* **9**, 340–346 (1998).

58. Pahl, S. & Wyles, K. J. The human dimension: How social and behavioural research methods can help address microplastics in the environment. *Anal. Methods* **9**, 1404–1411 (2017).

59. Bethlehem, J. Selection Bias in Web Surveys. *Int. Stat. Rev.* **78**, 161–188 (2010).

60. Sjöberg, L. The Methodology of Risk Perception Research. *Qual. Quant.* **34**, 407–418 (2000).

61. Hartley, B. L. *et al.* Exploring public views on marine litter in Europe: Perceived causes, consequences and pathways to change. *Mar. Pollut. Bull.* **133**, 945–955 (2018).

62. BMUB/UBA. *Umweltbewusstsein in Deutschland 2016*. https://www.umweltbundesamt.de/publikationen/umweltbewusstsein-in-deutschland-2016 (2017).

63. Oppenheim, A. . *Questionnaire Design*. (Continuum International Publishing Group Ltd., 2000).

64. Husson, Josse, Le & Mazet. *R: A language and environment for statistical computing*. (R Foundation for Statistical Computing, 2007).

65. Noguchi, K. *et al.* Package 'nparLD' T| Nonparametric Analysis of Longitudinal Data in Factorial Experiments. (2015).

66. Feys, J. Nonparametric Tests for the Interaction inTwo-way Factorial Designs Using R. *R J.* **8**, 367–378 (2016).

67. Benavoli, A., Corani, G. & Mangili, F. *Should We Really Use Post-Hoc Tests Based on Mean-Ranks? Journal of Machine Learning Research* vol. 17 (2016).

68. Davies, H. J. *et al.* Business attitudes towards funding ecosystem services provided by urban

519 forests. *Ecosyst. Serv.* **32**, 159–169 (2018).

520 69. Beasley, T. M. & Schumacher, R. E. Multiple regression approach to analyzing contingency
521 tables: Post hoc and planned comparison procedures. *J. Exp. Educ.* **64**, 79–93 (1995).

522

Acknowledgements

In advance of this survey, a pilot study was designed in collaboration with Bethan Williams.

We would like to take the opportunity to thank everyone who helped to distribute our online survey on social media. We are grateful to Professor David Coggon for providing feedback on an earlier version of this manuscript.

Author contributions

Both authors conceived the work. CT carried out the analytical work & drafted the manuscript. MDH supervised the work. Both authors have discussed the results, commented on and amended the manuscript.

Additional Information

Supplementary information

Supplementary information accompanies this paper at xxxx

Data availability

All data supporting this study are openly available from the University of Southampton repository at https://doi.org/10.5258/SOTON/D1379.

Funding

This work was supported by the EPSRC Doctoral Programme, a Southampton Marine and Maritime Institute Leverhulme Trust Doctoral Scholarship and the Blue Marine Foundation, London, UK. The funding bodies did not have any involvement in this study.

Ethical approval

Ethical approval for this research was granted by Ethics and Research Governance Online (ERGO REF41938) at the University of Southampton in compliance with the UK Concordat to Support Research Integrity. All methods were carried out in accordance with highest current international standards of ethical best practice.

Statement of competing interest

The authors declare no competing interest.

Fig. 1 – Mean level of concern (± standard deviation) of selected environmental issues of lay respondents (n = 1430) compared to topic-experienced^ respondents (n = 251). Survey results obtained in 2018/2019. *such as pesticides or heavy metals. ^acknowledged their previous or current work on the topic of plastics and/or microplastics as an environmental contaminant or involvement in a research project on this topic. Levels of concern: not concerned (1), slightly concerned (2), moderately concerned (3) and very concerned (4). See Table 1 for differences in rankings between environmental issues per group.

564 Fig. 2 – Response selection of lay respondents (n=1430) and experienced^ respondents (n=251) to a.
565 'Which of the following health problems in humans have been linked to microplastics?' and b.
566 'Answer true, false or don't know to the following statements:'. Statistical test results see Table 2;
567 statistical difference between categorical answers: *true, **false, ***don't know. Survey results
568 obtained in 2018/2019. ^ acknowledged their previous or current work on the topic of plastics
569 and/or microplastics as an environmental contaminant or involvement in a research project on this
570 topic.

571

572

Table 1 – Post-hoc analysis results: Statistical significance between environmental concern rankings per group (A. lay respondents, B, topic-experienced respondents) analysed with pairwise comparison Wilcoxon signed rank tests and Bonferroni correction.

A.	Air quality	Food source contamination	Plastic in general	Microplastics	Climate change	Increase in global population	Drought
Food source contamination	1						
Plastic in general	< 0.01	< 0.001					
Microplastics	0.226	< 0.05	1				
Climate change	< 0.001	< 0.001	0.134	< 0.01			
Increase in global population	1	1	< 0.001	< 0.05	< 0.001		
Drought	< 0.05	0.145	< 0.001	< 0.001	< 0.001	1	
Toxic chemicals in the oceans*	< 0.05	< 0.01	1	1	< 0.01	< 0.01	< 0.001

B.	Air quality	Food source contamination	Plastic in general	Microplastics	Climate change	Increase in global population	Drought
Food source contamination	1						
Plastic in general	< 0.001	< 0.001					
Microplastics	< 0.001	< 0.001	1				
Climate change	< 0.001	< 0.001	0.28	1			
Increase in global population	1	1	< 0.001	< 0.001	< 0.001		
Drought	0.07	1	< 0.001	< 0.001	< 0.001	1	
Toxic chemicals in the oceans*	0.08	< 0.01	1	0.24	< 0.001	< 0.05	< 0.001

578 Table 2 – Results of between group (lay/experienced) χ^2 test and subsequent posthoc (residual chi-

579 square) test to questions posed in Fig. 1. Bonferroni-adjusted p-value of 0.004.

Sub-question according to Fig. 1	χ^2	df	p	Significant difference according to posthoc test in response selection (between 'true', 'false', 'don't know')	Notes
Upsetting of the hormonal system	25.98	2	<0.000001	'false' (p<0.0001); 'don't know' (p<0.004)	
Lung irritation/ breathing problems	31.83	2	<0.000001	'false' (p<0.000001)	
Cancer	30.61	2	<0.000001	'false' (p<0.000001)	
Stomach upset	29.02	2	<0.000001	'false' (p<0.000001)	
Kidney disease	62.04	2	<0.000001	'false' (p<0.000001)	
Poisoning	32.61	2	<0.000001	'false' (p<0.000001)	
Headaches	24.75	2	<0.000001	'false' (p<0.000001)	
Microplastics have been proven to cause some types of cancer	60.65	2	<0.000001	'false' (p<0.000001)	
Microplastics have been found in human food sources	26.66	2	<0.000001	'true' (p<0.00001); 'don't know' (p<0.00001)	Yates correction
Marine organisms have been shown to consume microplastics	16.05	2	<0.000001	'true' (p<0.001); 'don't know' (p<0.001)	Yates correction

580