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Exploring expert perceptions about microplastics: from sources to potential solutions

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Abstract

Concern about plastic pollution, including microplastics, is high amongst European citizens, and effective actions are needed to reduce microplastic pollution. However, there is still uncertainty and debate about the major sources, impacts, and in particular the solutions. The aim of the current study was to gather expert perceptions about the risks of different microplastic sources to the natural environment and human health (measured as the likelihood and severity of negative impacts resulting from exposure), as well as the feasibility and effectiveness of different solutions. Experts were identified as scientists working on plastic. Usable responses were received from 73 experts with an average of 5 years' experience in plastic research. Experts thought that there was currently stronger evidence for microplastic impacts on the natural environment than on human health, that, accordingly, the risks were higher, and they were more worried about impacts on the natural environment than on human health. Experts perceived tyre particles and textile fibres to be the main sources of microplastics presenting risk for both natural environment and human health. Various solutions were rated as relatively effective and feasible overall. Solutions that were rated as above-average in terms of effectiveness and feasibility included education and awareness programmes, washing machine filters, bans of plastic items, simplified design of products, and circular economy approaches. However, experts were uncertain about the effectiveness and feasibility of recovery and clean-up solutions, with overall ratings for these being below-average in comparison to other solutions earlier in the plastic life cycle. An improved understanding of expert views on these matters could inform the distribution of limited research resources and help prioritise research questions, especially with regard to potential solutions and interventions which will be critical for the success of the UN Plastics Treaty.

Keywords Social data, Survey, Microplastics, Plastic pollution, Risk perception, Human health, Natural environment

Introduction

It is not easy to imagine everyday life without products made out of, or wrapped in, plastics. Plastics are inexpensive, versatile, lightweight and durable and bring many societal benefits including the potential to reduce the carbon footprint of transportation [1]. The problem with plastics is not necessarily their mere existence [2], instead problems surround production, usage, and disposal practices, and sheer quantities, which pose substantial threats to marine and freshwater ecosystems [3, 4] and beyond. The current work focuses on microplastics, small plastic

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particles less than 5 mm in size, as an environmental pollutant [5].

To effectively address the issue of environmental pollution, it is essential to prioritize research efforts by determining consensus and uncertainties in the field. Boonstra et al. [6], for example, found that contamination and waste was perceived as one of the major threats for marine environments by ecologists and environmental scientists. Provencher et al. [7] identified emerging research questions on plastic pollution in the natural environment by asking global experts in the field of plastic pollution to rank pre-defined topics. The expert sample identified as top priority questions plastic sources in the aquatic environment, successful policy tools, effects of ingested chemicals to aquatic biota, standardized methods for sampling and reporting plastics, and hotspots of plastics in aquatic environment. Additionally, the authors commented that the current natural science focus on priorities in plastics research may shift with the emerging inclusion of social sciences in the plastics discourse.

Social science research targeting environmental issues is increasing and, has shown widespread and growing societal concern about the negative impact of marine plastic and microplastics pollution on the natural environment and, more recently, also on human health [8–12]. A survey showed that European citizens are worried about the environmental impact of every-day plastic products and microplastics [10], and a study looking at four UK newspapers found widespread coverage of the issues, but the focus was almost exclusively on the problems, with very little coverage given to potential solutions [13]. Given the "UN Plastic Treaty" in preparation for 2024, a stronger focus on solutions is urgently needed (cf. Thompson et al. [14]).

In contrast to the public perception data, there is still debate around the exact magnitude and extent of negative impacts of microplastics on the natural environment, and human health effects are not yet sufficiently studied to make clear conclusions around risk [8, 15, 16]. While this debate carries on, media coverage has been found to convert "uncertain" risks to "actual" risks [17] and while there is social data on (micro)plastics perceptions of the general public [9–11] and specific stakeholder groups [18, 19], little research [6, 7, 20] to date describes the views of more informed stakeholders such as researchers focusing on (micro)plastics.

The primary purpose of the current research, therefore, was to better understand expert perceptions of microplastics, exploring their views on the current state of the evidence regarding microplastics impacts, their worries and perceptions about the impacts of different microplastics sources on the natural environment and human health, as well as their perceptions of potential solutions. This approach can help identify areas of uncertainty and identify future research questions as well as provide input into the debate around microplastics risks and solutions across the plastic life cycle.

Risk

The natural environment and humans are exposed to microplastics [21], but formal risk assessments are currently limited. This is partly a result of lack of data and of variation in methods used which limits inter-comparability of studies [15, 22]. Moreover, research on microplastics in some compartments, such as terrestrial and atmosphere, is still scarce, and research relating to microplastics and human health is very limited [15]. Nevertheless, SAPEA [21] and Koelmans et al. [22] stated that microplastics risk assessments – addressing its multiple dimensions and characteristics – are improving and aim to determine, not if, but when and where, microplastics pose risks to the natural environment and human health.

Technical assessments of complex, specific risks based on different metrics can be difficult to interpret and act on by non-experts. Therefore, approaches have been suggested to integrate and communicate information from highly diverse risk studies. Mehinto et al. [23] suggested a risk framework based on threshold levels related to microplastics concentrations using species sensitivity distributions. This derives categories of concern partly based on expert judgement, in order to inform risk management and environmental decision-making. A related, but more generic approach that relies on the classic risk parameters of likelihood and severity is the risk matrix [24–26]. Here, risk is mapped onto two dimensions – the likelihood/probability of the hazard occurring and the severity/impact/consequences when it occurs. For example, based on Fletcher's review about qualitative risk assessment [25], the approach was used by the Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection (GESAMP, [27]) to assess plastic and microplastics risk in the marine environment and by Roman et al. [28] to assess plastic pollution impacts on wildlife in the Mekong and Ganges river basins. In the present study, we used the risk matrix to capture experts' risk perception by asking them to rate the likelihood and severity of negative impacts occurring as a result of exposure to a hazard – in this case, different microplastics sources.

Microplastics sources and solutions

Primary microplastics are plastics purposefully manufactured in small sizes e.g. pellets for industrial production, plastic powders, microbeads in cosmetics etc. In contrast, secondary microplastics are larger plastic items which break down e.g. textiles, paints, tyres etc. [29]. Microplastics sources are as diverse as their characteristics and "the microplastic" does not exist, as thousands of classifications of synthetic polymers are used at present [3]. These plastics differ in constituent molecules, size, structure, shape and colour [30].

Initial research in this area focused on microplastics pollution and its impact specifically on marine environments [5, 29, 31–33] but microplastics have now been found in a variety of other environmental settings, e.g. in the atmosphere, soil, freshwater, drinking water and food [21]. Major European cities are surrounded by rivers which can be entry points for microplastics and pathways for further distribution of microplastics into various environments [3]. Siegfried et al. [34] estimated the amount of microplastics released by four sources from rivers to marine environments. Their results show that, in Europe, the major sources of microplastics pollution in marine environments with freshwater systems as pathways are tyre and road wear particles (42%), followed by synthetic fibres released during laundry (29%). The model calculated that plastic fibres in household dust (19%) and microbeads in cosmetics (10%) played a smaller part. Microplastics diffusion differs between European rivers as it is influenced by societal and economic developments, next to technological conditions such as sewage treatment [34]. Moreover, tyre wear particles are found in close proximity to roads and appear to be one of the key sources for microplastics pollution [35, 36]. A further case study at the Swedish west coast demonstrated that plastic pellets are released in their millions annually during production [37]. Plastic pollution, including microplastics, can arise through the whole product life cycle, from its production, use, to its disposal. It can originate from local or distant sources [21]. As microplastics can arise from many different sources we based our final selection for the survey on GESAMP [29].

It is critical to move beyond the understanding of distributions and effects of microplastics (the problem) and include the question of "what to do" to decrease microplastics release into the environment (the solutions). In a recent keynote on EU chemical safety regulation (REACH), the European Chemicals Agency (ECHA) stated that the existing evidence is enough to legislate the release of microplastics and a non-threshold risk assessment is supported, meaning that "uses of microplastics that result in releases to the environment pose a risk that is not adequately controlled and should be minimised" ([38], slide 14). Industry, economic, behavioural and political solutions are key components to solving this "wicked problem", and consideration of interventions across the complete life cycle of plastic is needed to tackle plastic and microplastics pollution effectively [39] https://www.lifecycleinitiative.org/life-cycle-approach-to-plastic-pollution/) [40]. When asking Europeans about choosing the most effective actions to tackle environmental problems, change of consumption behaviour (33%) and change of production and trading (31%) were selected most frequently [10]. Prata et al. [39] provided a summary of current solutions to tackle plastic and microplastics pollution during production, consumption and disposal and concluded in their review that an overall reduction of (micro)plastics impacts can only be achieved through the improvement of the plastic life cycle tackling the four R's: reduce, reuse, recycle and recover within an integrated waste management system internationally. It is unlikely that plastics production and use will cease completely. However, design improvements, use of alternatives, less plastic consumption, better recycling and a change towards a circular economy have been named as the way forward [39].

One key determinant for bottom-up change is the availability of alternatives. For example, an emerging alternative offered in supermarkets are bio-based or biodegradable plastics bags instead of conventional ones. Even though consumers hold positive attitudes towards bio-based plastics and are willing to pay more for such alternatives [41], we need to be cautious. Terminology such as the prefix "bio" could potentially lead to littering behaviour caused by the misperception that these plastics will not harm the natural environment, as research showed that consumers overestimate the benefits of biodegradability [41]. Other issues are the risk of biodegradable plastics being another microplastics source, contamination of waste streams and competition for natural resources.

Inspired by Dietz et al.'s [42] research on energy consumption, Pahl et al. [43] called for action to analyse the potential/feasibility of changing current practices and behaviours (i.e. behavioural plasticity), and the effectiveness of such changes. Some changes may be very feasible but not effective, while others may be highly effective but not currently feasible. Identifying those actions which are judged both feasible and effective is a first step in highlighting the "low hanging fruit" of possible actions to reduce plastic emissions. Overall, more comprehensive evaluations of solutions and interventions including behavioural-, policy-, technical- or system changes are needed to develop evidence-based recommendations [14, 43]. Therefore, a key part of the current research was to obtain expert judgements of the feasibility and effectiveness of various actions that have been proposed in the literature (e.g. [39]). Moreover, to be coherent with the risk matrix approach, we mapped the perceived effectiveness and feasibility in a solution matrix.

Aims of this study

The current research aimed to capture the views of experts actively researching plastics and microplastics and feed into the debate about the current state of the evidence regarding microplastic risks, impacts and solutions, while also analysing how certain or uncertain experts were in their views. We build on Thiele & Hudson [20], Prata et al. [39], Provencher et al. [7] and the SAPEA Report [21], by exploring expert views of specific sources named in the literature and, for the first time, of solutions, using a cross-sectional survey with closed and open-ended questions. This work is part of the H2020 LimnoPlast project (www.limnoplast-itn.eu) [44], which integrates social and behavioural science contributions into an interdisciplinary research approach to tackle microplastics in Europe's freshwater ecosystems. In short, the current research focused on the following research questions (RQs) spanning four main themes:

Theme 1: current state of the evidence

RQ1) How strong do experts perceive the current evidence to be for the impacts of microplastics on the natural environment relative to human health?

Theme 2: risk perception – worry

RQ2a) Are experts more worried about the negative impact of macro- or microplastics?; RQ2b) Are they more worried about the impacts of macro- and microplastics on the natural environment or human health?; RQ2c) If experts are worried, what specifically are they worried about and why?

Theme 3: risk perception – perceived risk of the impact across microplastics sources

RQ3a) How risky are sources of microplastic impacts perceived to be for the natural environment?; RQ3b) How certain are experts about the impacts on the natural environment across different microplastics sources?; RQ3c) How risky are microplastics sources impacts perceived to be for human health?; RQ3d) How certain are experts about the impacts on human health across different microplastics sources?; RQ3e) What do experts perceive as impactful microplastics sources and why?; RQ3f) Do experts' ratings differ between the natural environment in comparison to human health?

Theme 4: solution perception—effectiveness and feasibility

RQ4a) How effective and how feasible do experts perceive microplastics solutions to be?; RQ4b) How certain are experts about the effectiveness and feasibility of different microplastics solutions across the plastic life cycle?; RQ4c) What do experts perceive as impactful microplastics solutions and why?

The ultimate aim of our study was to provide an overview of expert perceptions of microplastic sources and solutions, which – together with results from environmental and technical research – can be used to inform future research and action.

Method

Participants—expert identification

Experts were invited to complete an online survey that was publicised during the MICRO2020 conference as well as through the authors' project-related networks (see procedure). In total we received 97 complete responses with a completion rate of 32% once participants had started the survey. Twenty-four responses were excluded because they had less than one-year experience in the field of plastic research, a minimal threshold we used to define expertise. The final sample consisted of 73 experts (54.8% Female, 41.1% Male, 1.4% Non-binary, 2.7% Prefer not to answer) with an average of 5 years of experience studying plastics ($M = 5.25$, $SD = 6.16$). The experts lived in 21 different countries – with Germany (42.5%), USA (8.2%) and Canada (6.8%) hosting the largest number. Their research was primarily funded publicly (72.1%) and the majority were working specifically on microplastics (84.9%) within the natural sciences (64.4%). Moreover, most experts were interested in protecting both the natural environment and human health (46.6%), closely followed by only protecting the natural environment (45.2%) and a minority was only interested in protecting human health (8.2%).

Social survey tool

The questions are shown in Table 1 in the order in which they were displayed to the participants. A randomisation of the item order was not possible due to constraints of the JISC survey provider. At several points participants had the added option of explaining their answers using open-ended text boxes. These responses allowed us a richer insight into their thoughts on specific issues.

Respondents were asked to rate the following list of sources (Table 2).

The following microplastic solutions were displayed for rating effectiveness and feasibility (Table 3).

Procedure

Piloting was undertaken with researchers from the International Marine Litter Research Unit at the University of Plymouth and early stage researchers from the LimnoPlast project. Survey invitations were distributed during the MICRO2020 conference via twitter posts and the LimnoPlast bi-weekly webinar series on microplastics (#microplastinar). We also sent direct email invitations to plastic-focused research groups and

Table 1 Survey questions and items

Topic & source	Item	Scale
Personal area of interest	Generally speaking, how interested are you personally in protecting the natural environment compared to protecting human health?	7-point rating scale from 1 (I am primarily interested in protecting the natural environment), 4 (I am equally interested in protecting both) to 7 (I am primarily interested in protecting human health)
Risk perception: worry Partly adapted from Special Eurobarometer (2020) [10] & Van der Linden (2015) [45]	How worried, if at all, are you about the current impact of everyday products made of plastic/ microplastics on the natural environment/ human health?	7-point rating scale from 1 (Not at all worried) to 7 (Extremely worried), and 99 (Don't know)
	If you have indicated that you are worried for any of the above, please briefly state what impacts you are specifically worried about. *(optional)*	Open-ended question
Quality of evidence perception Adapted from Pahl, Richter & Wyles (2022) [43]	In your opinion, how good is the current state of the microplastics evidence regarding the impact on the natural environment/ human health?	7-point rating scale from 1 (Very poor) to 7 (Very good), and 99 (Don't know)
Risk perception: likelihood and severity of microplastics impacts on the natural environment and human health Adapted from Van der Linden (2015) [45]	How likely do you think it is that microplastics from the following sources are having a negative impact on the natural environment/ human health?	7-point rating scale from 1 (Not likely at all) to 7 (Extremely likely), and 99 (Don't know)
	How severe do you think any negative impacts of microplastics from the following sources are for the natural environment/ human health?	7-point rating scale from 1 (Not severe at all) to 7 (Extremely severe), and 99 (Don't know)
	In your opinion, are there other sources of current microplastics pollution that are not covered above? *(optional)*	Open-ended question
	In your opinion, is there a particular microplastics source which has the most impact on the natural environment and human health? Please state briefly why. *(optional)*	Open-ended question
Solution perception: effectiveness and feasibility	How effective do you think each potential solution might be in reducing current microplastics pollution?	7-point rating scale from 1 (Not effective at all) to 7 (Extremely effective), and 99 (Don't know)
	How feasible do you think each potential solution might be to reduce current microplastics pollution?	7-point rating scale from 1 (Not feasible at all) to 7 (Extremely feasible), and 99 (Don't know)
	In your opinion, are there other solutions (technical, behavioural or policy related) that could reduce current microplastics pollution that are not covered above? *(optional)*	Open-ended question
	In your opinion, what is the most effective and feasible solution to reduce current microplastics pollution? Please explain briefly why. *(optional)*	Open-ended question
Socio-demographics	How would you describe your gender?	Nominal Scale: Male/Female/ Non-Binary/ Prefer not to say
	How old are you?	Metric Scale
	What is your country of residence?	Open-ended question

Table 1 (continued)

Topic & source	Item	Scale
Expert identification Partly adapted from Provencher et al. (2020) [7]	How would you describe your career stage?	Ordinal Scale: Early/ Mid/ Established/ Prefer not to answer
	Do you participate in the field of plastic research?	Nominal Scale: Yes/ No/ Prefer not to answer
	If yes: For how many years?; How is your research funded primarily?; Do you work on microplastics specifically?; In what discipline primarily?; In what geographical region have you studied plastic? (optional) *If no:* How, if at all, is your position related to plastic?	*Funding:* Public/ Industry /Both/ Other/ Prefer not to answer; *Microplastics research:* Yes/No/ Prefer not to answer; *Other items:* Open-ended question

If the source was not specified, we phrased the question

Table 2 Microplastics sources

Primary microplastics	Secondary microplastics
(1) Pre-production plastic pellets	(2) Textiles (e.g. microfiber)
(3) Cosmetics, detergents, and cleaners (e.g. microbeads)	(4) Disintegrated parts of larger consumer products (e.g. food & drink packaging, single-use plastic bags)
	(5) Fragments and pieces from industry and construction (e.g. paints)
	(6) Fragments and pieces from agriculture, aquaculture, fishing
	(7) Tyre abrasion
	(8) Synthetic/artificial surfaces in recreational sports and children's playgrounds (artificial turf, RUBKOR surfaces)
	(9) Biodegradable plastic products
	Other (you can say more below)

Note: The final selection of the presented microplastics sources were based on GESAMP ([29], Chapter 2 Sources of Microplastics). The ratings were done twice, once for the natural environment impacts and once for human health impacts

individual researchers and placed invitations on two websites (https://chemiecluster-bayern.de/news/hot-seat-maja-grunzner-2/ [46] and http://www.sraeurope.eu/a-little-bit-of-your-time-for-an-experts-survey [47]). Responses were collected between 24th November 2020 to 24th March 2021. No incentives were provided. Participants were invited to reach out to the lead author to receive the results.

Data analysis

Data were analysed using the statistical software R version 4.1.4. To test for normality, we used QQ-plots and Shapiro–Wilk tests and adapted the analysis accordingly. To explore how experts perceive the current state of the evidence of microplastics impact on the natural environment in comparison to human health (RQ1) we conducted a non-parametric paired Wilcoxon-test, as the data was not normally distributed. In order to explore whether experts' worry about macroplastics and microplastics differed and if that worry varied for the natural environment and human health (RQ2a-b), we conducted a 2 (plastic size: macroplastics, microplastics) $\times$ 2 (target: natural environment, human health) ANOVA with repeated measures on both factors. We explored the likelihood and severity ratings for the natural environment and human health with scatterplots, in line with the risk matrix approach (Appendix Fig. 1). Moreover, we assessed the relationship between the likelihood and severity expert rating means with a Pearson correlation coefficient and computed a new risk variable. To investigate which sources were seen as risky (RQ3a; RQ3c) and how certain the expert sample was in their ratings (RQ3b; RQ3d), mean scores and the 95% confidence intervals (CI) for each source as well as the percentage of "don't knows" were calculated and presented in a graph for the natural environment and human health separately. This was followed by ANOVAs and post-hoc tests to determine differences in the respective ratings. To examine if the overall ratings differed for the natural environment and human health (RQ3f) a non-parametric paired Wilcoxon-test was conducted as the data was non-normally distributed.

To explore expert perceptions of microplastics solutions across the whole plastic life cycle (RQ4a-b), we adopted a similar approach to the ratings of microplastics sources above. The distribution of the effectiveness and feasibility ratings for the microplastics solutions were explored with scatterplots. We additionally assessed the effectiveness and feasibility ratings with a Pearson correlation. Moreover, mean scores, 95% CI and percentage of "don't knows" for the effectiveness and feasibility across each microplastics solution were calculated. The results were displayed in a joint graph separately for the effectiveness and feasibility. Additionally, to explore experts' worry (RQ2c) and perceptions around microplastics sources (RQ3e) and their thoughts on solutions (RQ4c) beyond the rating scales, we conducted a qualitative thematic analysis, representing the core categories, of relevant statements from the optional open-ended questions.

Results

State of the evidence

The experts felt that the current evidence of microplastic impacts on the environment[1] was stronger than evidence of impacts on health $W = 42$, $p < 0.001$, $r = -0.71$. (Environment: $Mdn = 0.00$, $M = -0.01$, $SD = 1.36$; Health: $Mdn = -2.00$, $M = -1.54$, $SD = 1.40$).

Risk perception: worry

Worry ratings

Respondents showed no significant difference in worry about macro- and microplastics, $F(1,72) = 2.75$, $p = 0.102$, $\eta^2 = 0.037$; macro $M = 5.09$ ($SD = 1.26$), micro $M = 4.93$

[1] To enhance the reading flow throughout the result section we described the natural environment as *environment* and human health as *health*.

Table 3 Potential microplastics solutions across the plastic life cycle

Solutions across the plastic life cycle
Design and production
(1) Different construction of synthetic materials for clothing (e.g. yarn type, textile construction) to reduce shedding of fibres
(2) Simplified design of products, e.g., avoidance of films and mixtures of different plastic types to facilitate recycling
(3) Increased use of biodegradable plastics
Packaging and distribution
(4) Reduction of single-use plastic packaging
(5) Bans of plastic items such as straws, disposables etc
(6) Better labelling of cosmetic and cleaning products that contain microbeads (where these still exist) to allow consumer choice
Use and maintenance
(7) Introduce widespread schemes for more reuse of plastic items by consumers, e.g. bring your own coffee cups, bring your own shopping containers
(8) Increased reparability / longevity of products, e.g. electronics
Disposal
(9) Financial incentives for recycling of plastic items by consumers
(10) Introduction of harmonised recycling systems nationally and internationally
(11) Deposit return schemes for plastic items such as bottles
Recovery / Clean-up
(12) Advanced tertiary technologies: including clariflocculation (phosphorous removal), membrane processes (membrane bioreactor, ultra- and nanofiltration), and activated carbon processes
(13) Electrostatic separation process in industrial wastewater
(14) Washing machine filters
(15) Tyre wear particle collector on the car
(16) Capture of microplastics from sports fields and playgrounds
Systems-based approaches
(17) Extended Producer Responsibility (need for the producer to take used product back for reusing or recycling and with it "forcing" producer to take product life cycle into account) and fines for spillages
(18) Circular economy approaches from design to end-of-life
(19) Financial burdens such as a "plastic tax" or charges to make any plastic product more expensive and thereby reduce the use
(20) Widespread education and awareness programmes to reduce plastic use through better consumer decisions

The presented solutions were partly adapted from Prata et al. [39] and informed by the LimnoPlast project as well as the authors expertise. The Plastic Life Cycle was adapted from UNEP's Life Cycle Initiative (https://www.lifecycleinitiative.org/life-cycle-approach-to-plastic-pollution/) [40]

($SD = 1.33$). However, consistent with beliefs about the extent of current evidence, worry was significantly higher for the environment than for health, $F(1,72) = 69.95$, $p < 0.001$, $\eta^2 = 0.493$ (environment $M = 5.66$, $SD = 1.67$; health $M = 4.36$, $SD = 1.60$) Fig. 1.

Worry statements

In the open-ended statements (Table 4), experts reported that they were specifically worried about the uncertainty around microplastics quantity and its unknown effects. Additionally, some experts did worry about the known and the potential effects of plastic and microplastics. Furthermore, multiple experts emphasized their worry about chemicals and additives of plastic and their potential negative impacts. Besides the personal worry, it was voiced that *"dividing [the] natural environment and human health is artificial, if you affect the natural environment you will affect human health." (Female, Established Career, Netherlands).*

Risk perception: perceived risk of the impact across microplastics sources

Natural environment

There were significant differences in the perceived riskiness to the environment of different sources of microplastics, $F(8, 450) = 6.64$, $p < 0.0001$, $\eta^2 = 0.106$; means displayed in Fig. 2A and Appendix Table 1. Tukey's HSD post hoc tests showed that the risk of tyres ($p < 0.0001$, 95% C.I. = [0.69, 2.48]), textiles ($p < 0.001$, 95% C.I. = [0.37,2.16]), macroplastics ($p < 0.001$, 95% C.I. = [0.38, 2.17]) and agriculture fragments ($p < 0.01$, 95% C.I. = [0.28, 2.07]) was rated as higher than that of plastic pellets. Tyres ($p < 0.0001$, 95% C.I. = [0.48, 2.27], textiles $p < 0.01$, 95% C.I. = [0.16, 1.94], macroplastics ($p < 0.01$, 95% C.I. = [0.17, 1.95]) and agriculture fragments ($p < 0.05$; 95% C.I. = [0.07, 1.85]) were rated higher than the risk of biodegradable plastics. The risk of tyres ($p < 0.05$, 95% C.I. [0.09, 1.87]) was also rated higher than of artificial surfaces. There was no statistically significant

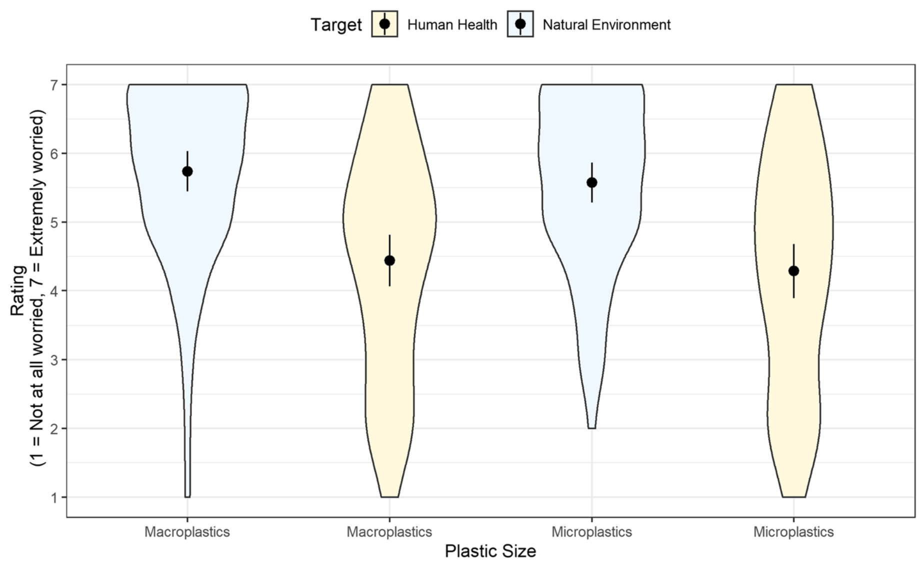

Fig. 1 Distribution and mean (with 95% CI) of the expert worry ratings about everyday products made out of plastics (macroplastics) and microplastics on the natural environment and human health

Table 4 Open-ended answers selected to illustrate responses to "If you have indicated that you are worried for any of the above, please briefly state what impacts you are specifically worried about."

Worry statements
Uncertainty
"[…] the unknown worries me most." (Female, Early Career, UK) "Microplastics are still not fully investigated and understood, that's the creepy part of it. […]" (Male, Early Career, Germany) "the uncertainty – there might be a lot more microplastic e.g. on the seafloor than we know […]" (Female, Early Career, Portugal) "The unknown effects of plastics on humans, the prevalence of plastics in the natural environment and the harms of plastics to marine life" (Female, Early Career, Netherlands)
Effects/ Impact of (micro)plastics
"physical (consumption/entanglement) and chemical (physiological) effects of materials and additives on organisms. [The] incorporation of plastics and their components into natural compartments (e.g. changes in sand composition) [and I am] mostly concerned about endocrine disruption in humans" (Female, Early Career, Canada) "chemical leaching impacts" (Female, Early Career, Australia) "[…] Especially the additives come into account again, as they leach out more easily and/or deeper in the body as microplastics can into the blood circle and accumulate in the body. Same issue with the natural environment." (Male, Early Career, Germany) "[…] there are bigger concerns for the natural environment. But reduced energy uptake, additives or chemical adsorption making plastics more harmful to flora and fauna. […]" (Female, Early Career, UK)

difference in the risk ratings for the environment between the rest of the sources. Dependent on the source, 3%-19% of the experts responded with "don't know" (see Fig. 2 and Appendix Table 1).

Human health

There were also significant differences in the perceived riskiness to health from different sources of microplastics ($F(8, 432) = 4.00$, $p < 0.001$, $\eta^2 = 0.069$; means displayed in Fig. 2B and Appendix Table 2). Tukey's HSD post hoc tests indicated that the mean risk rating of tyres ($p < 0.001$, 95% C.I. = [0.40, 2.59]), textiles ($p < 0.001$, 95% C.I. = [0.45, 2.65]), cosmetics ($p < 0.01$, 95% = [0.37, 2.57]), macroplastics ($p < 0.05$, 95% C.I. = [0.04, 2.25]) and artificial surfaces ($p < 0.1$, 95% C.I. = [0.01, 2.21]) was significantly higher than for pre-production plastic pellets. There was no statistically significant difference in the risk ratings for health between the rest of the sources. Consistent with the belief that evidence for health effects was less strong than for the environment, greater numbers of the experts responded "don't know" (16–22% depending on source, see Fig. 2B and Appendix Table 2).

Statements about microplastics sources and their potential impacts

In the open-ended part of this section, some respondents stated that textile fibres and tyres have the most negative impact due to their abundance and toxicity. Furthermore, microfibres from textiles were mentioned, as they were perceived as impactful due to the exposure in the air and risk of inhalation. Additionally, a few other sources were mentioned such as microplastics used in industry, (de) construction and agriculture because of the great exposure and risk of inhalation for material and construction workers. One expert also stated that biodegradable plastics could have impacts due to potential overuse.

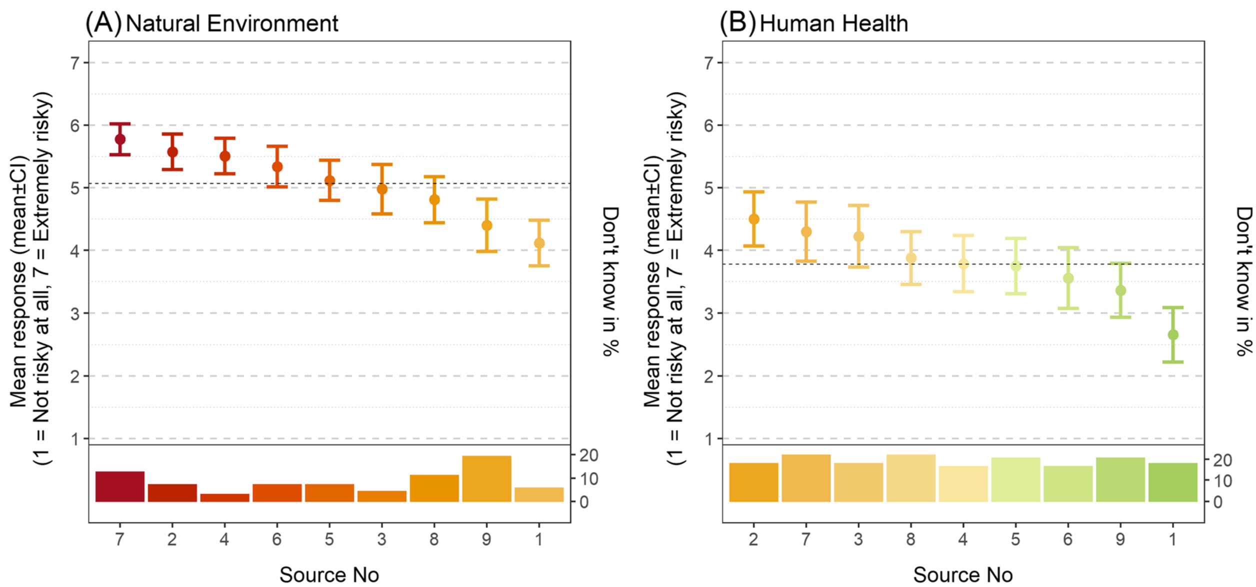

Fig. 2 Mean level of risk (with 95% CI), overall mean (indicated as dotted line) and don't knows in percentage (separated by solid line) for (A) the natural environment and (B) human health across nine different microplastics sources displayed from highest to lowest rating. *Microplastics sources:* (1) Pre-production plastic pellets; (2) Textiles (e.g. microfiber); (3) Cosmetics, detergents, and cleaners (e.g. microbeads); (4) Disintegrated parts of larger consumer products (e.g. single use food & drink packaging etc.); (5) Fragments and pieces from industry and construction (e.g. paints); (6) Fragments and pieces from agriculture, aquaculture, fishing; (7) Tyre abrasion; (8) Synthetic/artificial surfaces in recreational sports and children's playgrounds; (9) Biodegradable plastic products

Moreover, consumer products were mentioned due to the influence of big food companies as well as improper disposal practices (see Table 5).

Differences between the perceived risk for the natural environment and human health

Consistent with results so far, the perceived risk of different microplastics sources was greater for impacts on the environment than on health, $W = 80{,}761$, $p < 0.001$, $r = -0.56$ (Environment: $Mdn = 5.00$, $M = 5.07$, $SD = 1.49$; Health: $Mdn = 3.50$, $M = 3.78$, $SD = 1.84$).

Solution perception: effectiveness and feasibility

Effectiveness and feasibility ratings

A substantial proportion of the experts were unsure in their ratings of potential solutions. Overall, depending on the solution, 1–33% indicated that they did not know how effective it was and between 3–33% indicated that they did not know how feasible it was (Fig. 3 and Appendix Table 3). Experts were mostly uncertain about the solutions within the Recovery/ Clean-up stage. To explore the effectiveness and feasibility ratings of the solutions we created combined graphs displaying the average mean ratings, mean line and 95% confidence intervals (top-graphs) and percentage of "don't know" responses (bottom-graphs) of 20 different microplastics solutions across the plastic life cycle and from a systems approach perspective (see Fig. 3). A detailed overview of the effectiveness and feasibility mean ratings, standard deviations and "don't know" responses for each solution can be found in the Appendix Table 3.

Effectiveness and feasibility matrix

Figure 4 shows the distribution of potential solutions to reduce microplastics across the plastic life cycle and various system-based approaches (see complete list in Table 3). Using solutions as the unit of analysis, the average effectiveness and feasibility ratings for each microplastics solutions were not strongly correlated ($r(19) = 0.29$, $p = 0.22$). Using respondents as the unit of analysis, the correlations between the solution effectiveness and feasibility ratings ranged between $r(63) = 0.17$, $p = 0.19$ and $r(44) = 0.61$, $p < 0.001$.

On average, the experts rated the solutions to be relatively effective ($M = 5.26$, $SD = 0.6$) and feasible ($M = 4.98$, $SD = 0.7$). Figure 4 illustrates perceived feasibility and effectiveness of solutions. The scatterplot can be distinguished in four different quadrants: Top-left = *Below-average effective and above-average feasible*; top-right = *Above-average effective and feasible*; bottom-left = *Below-average effective and feasible*; bottom-right = *Above-average effective* and *below-average feasible*.

To give an overview (listed in no particular order), solutions rated as *above-average effective and feasible*

Table 5 Open-ended answers selected to illustrate responses to "In your opinion, is there a particular microplastics source which has the most impact on the natural environment and human health?"

Microplastics sources and their potential impact
Tyres
"[…] due to its high discharge volume and composition. and it's hard to reduce compared to cosmetics." (Non-binary, Early Career, US) "[…] based on the recent study on fish toxicity from chemicals present in tyre wear particles." (Female, Early Career, US)
Fibrous microplastics/ Synthetic microfibres
"[…] especially for humans. They are very abundant and have higher toxicity in comparison to regularly shaped particles. Human exposure through breathing might be relevant." (Female, Early Career, Germany)
Consumer/ Everyday plastic products
"[…] Concerning human health, consumer products—e.g. plastic bottles—may be a problem, that is not really focussed, because of lobbying by the big food-companies." (Male, Established Career, Austria)"[…] plastic packaging and cosmetics and other detergents have the largest impact because (I think) they are the most common sources for microplastics. They enter the environment by improper disposal or directly from our waste water. […]" (Female, Early Career, Germany)
Microplastics from industry, (de)construction and agriculture
"inhaling [microplastics] produced by abrasion […]" (Female, Early Career, Sweden)"for the environment, all the things that are used in big areas (e.g. agriculture) have a significant impact. […](Male, Established Career, Austria)
Biodegradable plastics
"difficult to say based on current evidence, I believe biodegradable plastics may be more of a risk given their in vitro toxicity and assumption of being biodegradable / less impactful, which can lead to overuse and potential unforeseen impacts. […]" (Female, Early Career, US)

included: Education and awareness programmes to reduce plastic use through better consumer decisions; Washing machine filters; Bans of plastic items such as straws, disposables etc.; Deposit return schemes for plastic items such as bottles; Reduction of single-use plastic packaging; Simplified design of products, e.g., avoidance of films and mixtures of different plastic types to facilitate recycling; Increased reparability / longevity of products, e.g. electronics; Circular economy approaches from design to end-of-life and introduce widespread schemes for more reuse of plastic items by consumers, e.g. bring your own coffee cups, bring your own shopping containers.[2]

Below-average effective and feasible rated solutions included: Capture of microplastics from sports fields and playgrounds; Advanced tertiary technologies: including clariflocculation (phosphorous removal), membrane processes (membrane bioreactor, ultra- and nanofiltration), and activated carbon processes[3]; Electrostatic separation process in industrial wastewater; Tyre wear particle collector on the car; Different construction of synthetic materials for clothing (e.g. yarn type, textile construction) to reduce shedding of fibres and the increased use of biodegradable plastics.

Above-average effective and below-average feasible rated solutions included: Financial incentives for recycling of plastic items by consumers; Financial burdens such as a "plastic tax" or charges to make any plastic product more expensive and thereby reduce the use; Extended Producer Responsibility (need for the producer to take used product back for reusing or recycling and with it "forcing" producer to take product life cycle into account) and fines for spillages; Introduction of harmonised recycling systems nationally and internationally.

Below-average effective and above-average feasible rated solutions included: Better labelling of cosmetic and cleaning products that contain microbeads (where these still exist) to allow consumer choice.

Moreover, using the graph and its quadrants to explore the distribution of the different solutions within the plastic life cycle stages, we found that solutions from all life cycle stages are presented in the *above-average effective and feasible* quadrant. Nevertheless, the majority of the recovery / clean-up solutions (which also have in common to be technical solutions) are found in the *below-average effective and feasible* quadrant.

Statements about microplastics solutions

Solutions which were not presented in the survey but were named by the experts in the open-ended section included national plastic recycling-, incineration- and landfill percentage targets, urban storm water treatments, international environmental plastic limits, incentives for improving waste management, reducing littering, labelling for liquid plastics and raising the price of plastic products.

When asked about the most effective and feasible solution, almost no technical solutions were mentioned and it was said that policy and behavioural measures as well as a reduction of plastic production and use is the way forward to tackle microplastics pollution (see Table 6). Additionally, one expert pointed out that they *"[…] don't think there is one solution that is more effective or feasible, but that all solutions should be used in tandem to create an overall reduction in various sources. This may look different by region based on plastic usage and what is found [in the environment]." (Female, Early Career, UK).*

[2] Reuse-schemes were rated as *above-average feasible* but as *average effective* (see Fig. 4).

[3] Activated carbon processes describe technologies such as granular activated carbon filters which can be applied in wastewater treatment plants to remove impurities (including microplastics) from water.

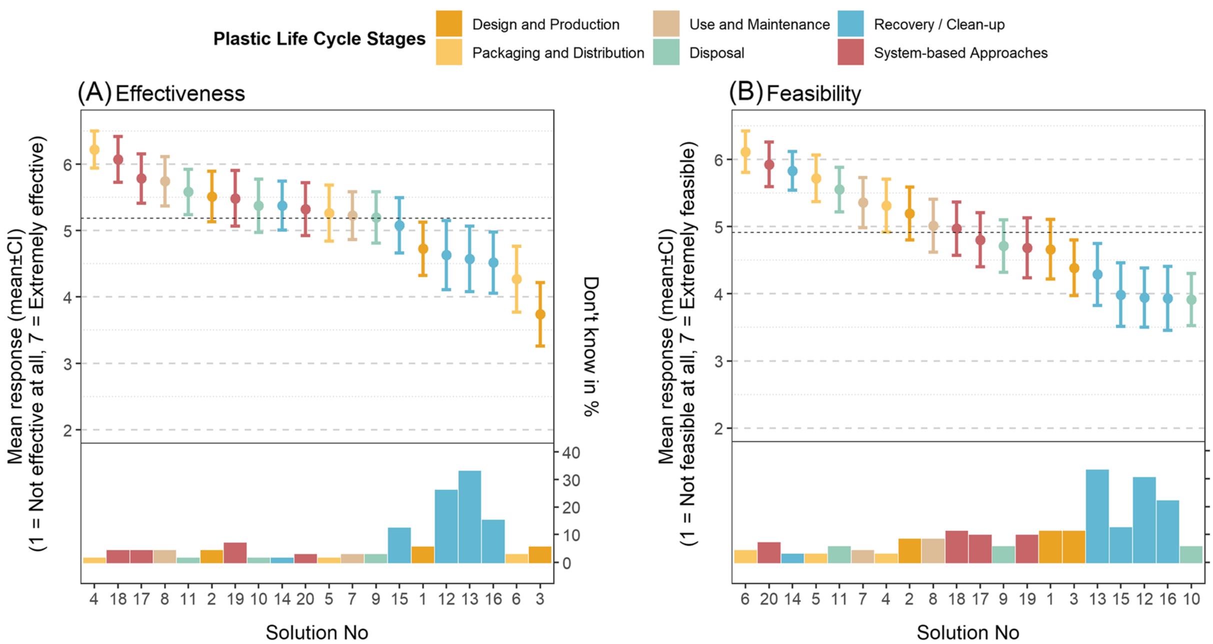

Fig. 3 Mean level of solutions (A) effectiveness and (B) feasibility ratings (with 95% CI), overall mean (indicated as dotted line) and separated don't knows in percentage (separated by solid line) of 20 potential microplastics solutions across the plastic life cycle and system approaches. *Microplastics solutions*: (1) Different construction of synthetic materials for clothing (e.g. yarn type, textile construction) to reduce shedding of fibres; (2) Simplified design of products, e.g., avoidance of films and mixtures of different plastic types to facilitate recycling; (3) Increased use of biodegradable plastics; (4) Reduction of single-use plastic packaging; (5) Bans of plastic items such as straws, disposables etc.; (6) Better labelling of cosmetic and cleaning products that contain microbeads (where these still exist) to allow consumer choice; (7) Introduce widespread schemes for more reuse of plastic items by consumers, e.g. bring your own coffee cups, bring your own shopping containers; (8) Increased reparability / longevity of products, e.g. electronics; (9) Financial incentives for recycling of plastic items by consumers; (10) Introduction of harmonised recycling systems nationally and internationally; (11) Deposit return schemes for plastic items such as bottles; (12) Advanced tertiary technologies: including clariflocculation (phosphorous removal), membrane processes (membrane bioreactor, ultra- and nanofiltration), and activated carbon processes; (13) Electrostatic separation process in industrial wastewater; (14) Washing machine filters; (15) Tyre wear particle collector on the car; (16) Capture of microplastics from sports fields and playgrounds; (17) Extended Producer Responsibility (need for the producer to take used product back for reusing or recycling and with it "forcing" producer to take product life cycle into account) and fines for spillages; (18) Circular economy approaches from design to end-of-life; (19) Financial burdens such as a "plastic tax" or charges to make any plastic product more expensive and thereby reduce the use; (20) Widespread education and awareness programmes to reduce plastic use through better consumer decisions

Discussion

Set in the context of UNEA5.2, the "Plastics Treaty" and the urgent need to move forward with actions and solutions [14], the aim of the study was to gauge how a group of experts in the field of (micro)plastics research perceive the risks of microplastics for the natural environment and human health from different sources, as well as how they view different potential solutions. The survey tool allowed us to describe responses quantitatively, including expressed uncertainty. We also added open-ended sections, which provided rich data by allowing experts to explain their thinking behind certain responses. These insights can contribute to the current debate about the harmfulness of microplastics and help us understand research gaps and evidence needs. Moreover, with an additional focus on solutions it provides suggestions for a way forward.

Summary of findings

Experts perceived the current state of the evidence of microplastics impact for human health as relatively poor and as neither poor nor good for the natural environment, which is in line with results from reviews of the scientific literature about microplastics [8, 17]. Despite the perceived difference about microplastics harm for the natural environment and human health, reports by the scientific microplastics community show that the broader consensus of experts seem to agree that microplastics should not enter the open environment and that the pollution needs to be stopped [5, 16, 21, 27, 29]. In past literature it was argued that "risks do not appear to be widespread at this point, but most scientists agree that it is not a question of if, but rather when, the environmental and human health risks of microplastic particles become apparent" [22].

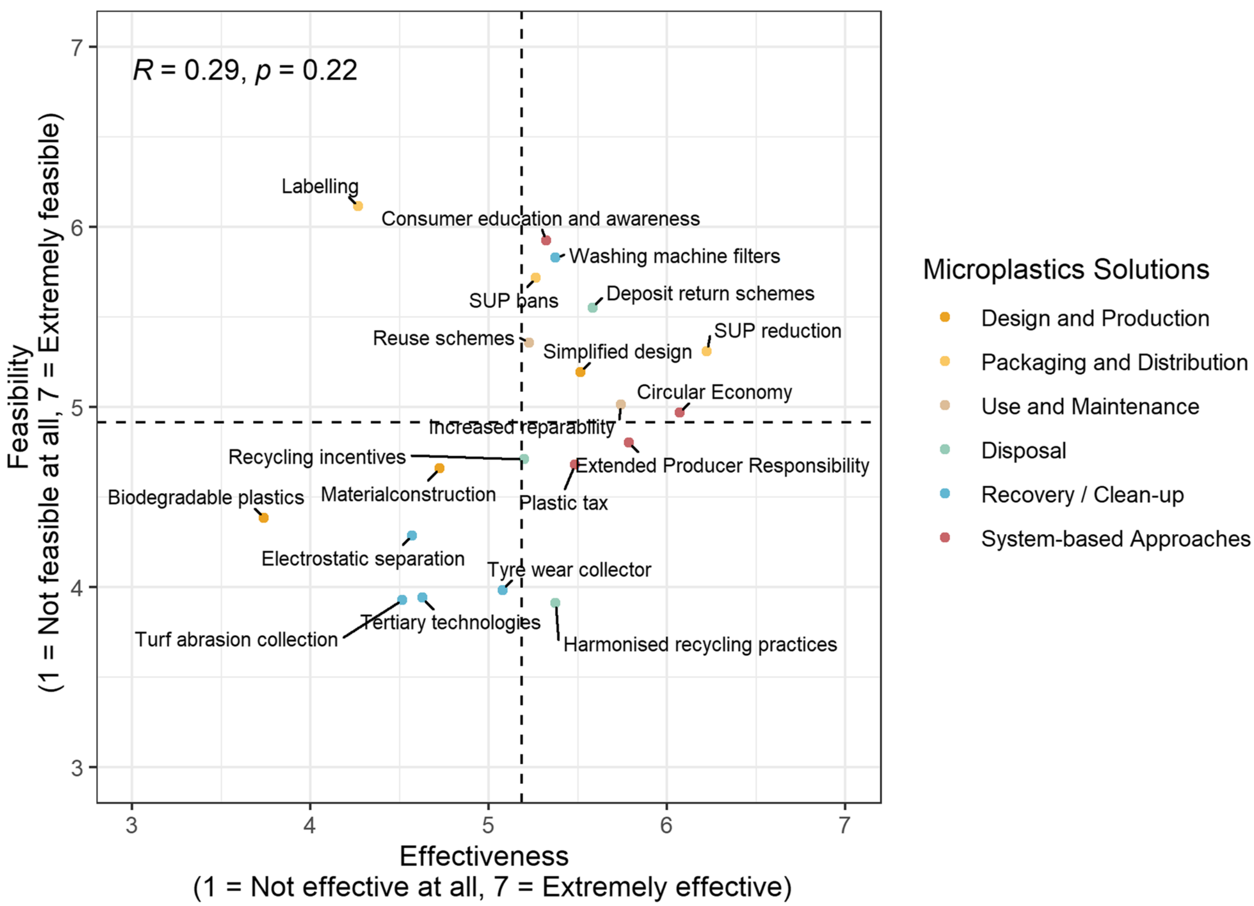

Fig. 4 Distribution of potential microplastics solutions across the plastic life cycle and system-based approaches separated into four different categories according to their effectiveness (below or above $M_{Effectiveness} = 5.18$) and feasibility (below or above $M_{Feasibility} = 4.91$)

Many experts said their worries were, at least in part, based on ongoing uncertainties about microplastics quantities and effects on the natural environment and human health, especially when talking about additives. Worry specifically adds a meaningful layer of analysis, as research in the context of climate change has shown that it was linked to adaptive behaviour to reduce the threat (e.g. Smith & Leiserowitz [48] demonstrated that worry about global warming was strongly associated with increased policy support). We hypothesize that this mechanism on an individual level might partly explain why researchers, even with the data gaps and inconclusive results, are calling for actions to reduce microplastics pollution now.

Despite our focus being on microplastics only, the topic is embedded into the discussion of environmental hazards generally such as climate change, drought and toxic chemicals in the ocean. For example, a recent survey [20] showed that (micro)plastics topic-experienced respondents (bachelor- and master students included) were most concerned about climate change but concern for plastic in general and microplastics followed closely.

In our study and in line with the worry ratings, microplastics across the different sources were perceived as riskier for the natural environment than for human health, with experts tending to be less certain about the impacts on the latter. Tyre abrasion and textiles were perceived as the riskiest sources for the natural environment and for human health (though the order for the latter was reversed), with some experts explaining that they perceived tyres and textiles as most impactful because of their abundance and potential toxicity. Overall, in the expert group, however, there was greater uncertainty about the risks from tyres than textiles. For tyre particles it was stated that they are difficult to reduce in comparison to other sources such as cosmetics and it was mentioned that textiles could be impactful for humans because of the possibility to inhale fibrous microplastics. In the open-ended replies some experts nominated additional sources as the most

Table 6 Open-ended answers selected to illustrate responses to "In your opinion, what is the most effective and feasible solution to reduce current microplastics pollution?"

Statements about perceived impactful microplastics solutions
Technical measures
"filters on washing machines" (Non-binary. Early Career, US)
Policy and behavioural measures
"wearing/choosing natural clothes instead of synthetic ones" (Female, Early Career, Germany)
"value [of] the environment in our economy [should be considered]. In capitalism, you need to create continuous growth… we can do that and benefit the planet if the environment had a value in our economies." (Male, Early Career, UK)
"combination of circular economy approach and EPR [Extended Producer Responsibility], including fines for spillage, supported by [a] tax for packaging [are the most effective and feasible solutions]. [The] main question for me [is]: What works better: E.g. [a] very thin plastic bottle which easily crushes and 'invites' to be thrown in [the] grey bin, versus [a] thicker wall bottle, which costs more material, but which feels safe to be 'store[d]' and [brought] back to [the] shop or [the] plastic recycling system?" (Male, Established Career, Netherlands)
"heavy financial punishment and governmental integrity/independence of lobbyism. [Making] politics for the people not the market." (Female, Early Career, Germany)
"starting at the top first. Incentivize[ing]/ require[ing] companies to take on responsibility, using all of the tactics that were mentioned in the survey. When companies can make more profit from investing in environmentally friendly alternatives, then we could see a big shift. Alongside of consumer education and awareness." (Female, Early Career, Germany)
"Behavioural and educational… because it impacts how we act in business, organisations, politics as well as our own lives. Providing well researched knowledge to the masses enables others to make informed decisions, companies to take the right paths and government to enforce change." (Female, Early Career, UK)
Reduction of plastic production and use
"[…] if you eliminate or minimize the source, you reduce the consequences." (Female Early Career, Germany)"a combination of bottom-up and top-down approaches. The 3 R policy says Reduce, Reuse, Recycle, therefore deposit schemes (reuse) and repair schemes (reuse) should receive more attention and funding when compared to recycle. I do not believe that recycling marine plastics into new products is a good solution due to the ability of plastics to absorb pollutants from their surrounding environment." (Male, Mid Career, Ireland)"[…] all the ideas to collect material and all the recycling activities are just the second-best solution […] because all the using, collecting und re-using plastics, just produces more and more micro-plastics." (Male, Established Career, Austria)"[…] prevention is necessary from key point source areas ([e.g.] washing machines, microbead bans, wastewater, landfill leaks)." (Female, Early Career, Netherlands)

impactful, e.g. consumer products and plastic packaging, as well as improper disposal, and distal causes such as the influence of food company lobbyists.

Biodegradable plastics and pre-production pellets were perceived as the least risky sources for both natural environments and human health, with some uncertainty about the impacts of biodegradable plastics. However, one expert perceived biodegradable plastic as risky because of the common assumption that they are less impactful which could lead to overuse.

Regarding potential solutions, better labelling of consumer products – a solution often suggested to guide consumer choices – was perceived as most feasible but was rated *below-average effective* in comparison with other solutions, e.g. awareness and education programmes. Washing-machine filters were rated as *above-average effective* and *above-average feasible,* with few respondents unsure. Furthermore, a solution currently implemented more and more, the increased use of biodegradable plastic, was rated as least effective as well as *below-average feasible* which might be based on the belief that biodegradable plastic may have unintended side-effects and turn from a solution to microplastics source.

Moreover, in comparison to the other plastic life cycle stages, almost all presented recovery and clean-up solutions (with the exception of washing machine filters) clustered together within the *below-average effectiveness* and *feasibility* quadrant, with experts expressing considerable uncertainty around these "end-of-pipe" solutions. Besides urban stormwater treatments, no further technical solutions were mentioned, and when experts were asked about the most impactful solutions, they focussed mainly on policy and behavioural measures to tackle microplastics pollution. Additionally, a holistic reduction of plastic production and use (incl. simplified design) was supported as the way forward. A few experts also mentioned focusing on a combination of solutions, especially within the first stages of the plastic life cycle while also adapting the solutions according to context (e.g. regional plastic use and plastic exposure).

Limitations

Despite the novelty of our findings, especially with respect to expert perceptions of solutions, we also recognise several limitations. First, the sample was self-selecting and the recruitment was based on the microplastics research community which were active on twitter during the MICRO2020 conference and the wider LimnoPlast researchers' network which led to the final sample of experts mainly in the Global North, despite us trying to increase diversity by sending out individual invitations to researchers in underrepresented countries.

No statistical power calculation was conducted as the potential expert sample was limited. Additionally, half of the sample consisted of (self-defined) early career researchers within the natural sciences and most open-ended comments were from females in their early career stage. Even though the results do not allow for generalisation about the views of the overall microplastics research community, they provide insights about perceptions of early career researchers within the natural sciences – a big and important group with an influence on future research.

Lastly, we also recognise that we preselected nine microplastics sources and twenty solutions across the plastic life cycle based on current literature. While this reduced participant burden, this approach may have missed some important sources and/or solutions. Nevertheless, a strength of our approach was the inclusion of open-ended response options where participants could and did add further examples and issues.

Implications and future research

One notable result was that uncertainty appeared to be an ever-occurring theme in the quantitative ratings as well as in the experts' statements, especially when the experts described why they were worried about plastic and microplastics. This suggests greater need for a more in-depth look into experts' understanding of microplastic causes and consequences, for example by using a mental model approach. Mental models are understood as "the sets of causal beliefs we 'run' in our minds to infer what will happen in a given event or situation" [49] and were recently applied to microplastics perception research of laypeople in Norway [12]. Studying experts' mental models could help us to learn about their individual thinking processes with respect to how they understand microplastics intuitively and contextually as well as identify experts' shared understanding about causes and consequences.

Furthermore, based on the experts' ratings we challenge the assumption, still present in some quarters, that solely trusting in technical innovations and focusing on clean-up solutions should be a main focus when mitigating microplastics pollution. Instead we urge to enhance regulatory (e.g. plastic bans, extended producer responsibility), behavioural (e.g. education and awareness programmes) as well as system-based measures (e.g. circular economy approaches). Furthermore, we want to point out that the sample of experts seemed to be sceptical about biodegradable plastics as a solution and therefore, biodegradable plastic impacts and also consumer behaviours should be studied carefully before implementing them as a mainstream alternative.

Conclusion

In conclusion, we want to emphasize that the focus should move towards impactful solutions tackling the "what-to-do-question", as researchers (cf. Koelmans et al. [22] SAPEA [21] Thompson et al. [14]) as well as ECHA [38] agree that there is enough evidence to act against microplastics pollution. Moreover, we argue that the data from this study suggests that experts working in the field are not centring around the idea that technologies used for clean-up or recovery will solve microplastics pollution and that this systems problem needs systems solutions. Hence, impactful and long-lasting changes can only be achieved by combined top-down (e.g. measures by governments such as extended producer responsibility and bans) and bottom-up (e.g. industry voluntary actions and consumer behaviour change) approaches.

Abbreviations

ECHA	European Chemicals Agency
GESAMP	Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection
SAPEA	Science Advice for Policy by European Academies
UNEP	United Nations Environmental Programme

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s43591-023-00055-5.

Additional file 1: Graphical abstract. **Appendix Fig 1.** Distribution and relationship of expert's likelihood and severity mean ratings (with regression line and 95% CI) for each microplastics source on (A) the natural environment and (B) human health. **Appendix Fig 2.** Mean level of likelihood and severity (with 95% CI), overall mean (indicated as dotted line) and don't knows in percentage (separated by solid line) for (A-B) the natural environment and (C-D) human health across nine different microplastics sources displayed from highest to lowest rating. **Appendix Table 1.** Means, standard deviations and percentage of don't know responses related to perception of microplastics risk for the natural environment. **Appendix Table 2.** Means, standard deviations and don't know responses in percent of the microplastics risk measures for human health. **Appendix Table 3.** Means, standard deviations and don't know responses in percent of the microplastics solution ratings.

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Authors' contributions

MG: Conceptualization, Methodology, Investigation, Formal analysis, Data curation, Writing—original draft, Writing—review & editing, Visualization. SP:

Conceptualization, Methodology, Writing—review & editing, Funding acquisition, Supervision. MPW: Methodology, Writing—review & editing, Supervision. RCT: Conceptualization, Writing—review & editing, Supervision, Funding acquisition. All authors read and approved the final manuscript.

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Availability of data and materials
The data was generated and analysed as part of the European Union's Horizon 2020 research and innovation project LimnoPlast and will be made publicly available in the respective Zenodo repository https://zenodo.org/communities/limnoplast/ after successful defence of the doctoral dissertation from Maja Grünzner. Please contact the corresponding author in the meantime.

Declarations

Ethics approval and consent to participate
Research Ethics Application Approval was received on 28th of October 2020 from the Health Faculty Research Ethics and Integrity Committee at the University of Plymouth under registration number 2316. Before responding to the survey, all experts were informed about the study aims, and they gave consent to participate voluntarily in the study.

Competing interests
The authors declare that they have no competing interests.

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