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Embedding citizens within airborne microplastic and microfibre research

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Abstract

Microplastics are ubiquitous in our environment but their presence in air is less well understood. Homes are likely a key source of airborne microplastics and microfibres to the environment owing to the frequent use and storage of plastics and textiles within them. Studying their presence, concentration and distribution in these environments is difficult without the participation of citizens due to accessibility challenges. Few studies have examined the intricacies of the prevalence of indoor microplastics and microfibres or the link between indoor exposure and behavioural and regulatory approaches that could reduce their concentrations. The application of a quintuple innovation helix framework, within which a co-creative citizen science research methodology is applied, provides an opportunity for citizens to shape the scientific method, ensuring that methods are accessible and appropriate for widespread use and designed by the citizen, for the citizen. Exploring behaviours and motivations in plastic and textile use by citizens with industry may reduce the generation of these particles. Future studies should consider the importance of citizen inclusion when designing research strategies for measuring and reducing microplastic concentrations in homes, enabling a nuanced understanding of their generation and distribution and facilitating the development of appropriate behavioural, industrial and regulatory messaging and mitigative measures.

Impact statement

Airborne microplastics and microfibres are found across the globe, from urban environments to pristine biospheres such as the Arctic. Whilst evidence is emerging of their distribution, little is known of their presence and concentration indoors, or if particular behaviours affect this, partly due to the field being in its infancy and due to the difficulty of measuring within homes. Applying co-creative methods allows citizens to shape, measure and inform solutions to fields that are human-centred. In the context of airborne microplastics and microfibre sampling, measurement and action, the co-creative approach provides the opportunity to both engage citizens in a rapidly developing field and inform measurement campaigns and understanding of both sources and solutions. Co-creating such approaches does not have to be city-specific or nation-specific, and its framework can be applied in whichever community or country requires it. It may also allow for comparisons across communities and countries with a diversity of housing, clothing and scientific experience. Fundamentally, it puts citizens at the heart of research that directly informs and benefits them.

Introduction

Two-thirds of the textiles in UK homes are synthetic (Henry et al., 2019) and, as they are used, fragments are released into the environment. Whilst public awareness of waterborne microplastics, for example, from washing, is thought to be relatively high, fewer people are aware of the presence of airborne microplastics and limited datasets have been collected on their distribution. This paper introduces citizen science as an approach that enables the measurement of airborne microplastics in homes, enhances awareness of the issue and gathers indoor microplastics data that would otherwise be difficult to obtain.

Microplastics, defined as "*any synthetic solid particle or polymeric matrix, with regular or irregular shape and with size ranging from 1 μm to 5 mm*" (Frias and Nash, 2019), have been well studied in the marine environment and their transport routes and environmental impacts are reasonably well understood. The presence and role of these microplastics in the transport of harmful pollutants in the marine environment (Zarfl and Matthies, 2010) have been the focus of work through the Stockholm and Basel Conventions (Amato-Lourenço et al., 2020). However, less is known about their presence in the air, their sources and distribution. To date, few publications have focused on the measurement of microplastics in air, but these have identified the presence of significant quantities of microplastics in urban air and in the Arctic and the Alps (Bergmann et al., 2019). A significant proportion of these microplastics are fibrous in appearance but very little is known of their origin. Large numbers of microplastic fragments have been found in both indoor and outdoor air samples, indicating that plastic is not just ubiquitous in the water we drink and the food we eat, but also in the air we breathe (Gasperi et al., 2018). Furthermore, our exposure to microplastic is likely to be higher via the airborne route (Catarino et al., 2018) and evidence also demonstrates likely health risks associated with their inhalation (Prata, 2018). In-vitro studies have shown associations with increased risk of Chronic Obstructive Pulmonary Disease (Dong et al., 2020), and other studies of lung cancer patients have identified the presence of non-mineral fibres (i.e., plant and plastic) in 83% of non-neoplastic lung specimens and 97% of malignant lung specimens (Pauly et al., 1998). More recently, Jenner et al. (2022) identified the presence of microplastics in all regions of human lung tissue, and they have also been found in human blood (Leslie et al., 2022). Considering the potential impacts on well-being and health, it is imperative to understand their sources, presence and distribution, particularly in environments in which we spend significant proportions of our time.

The presence and prevalence of fibrous airborne microplastics are complicated by our limited understanding of sources and exposure pathways. Indeed, microplastics are a current societal hot topic, but, excluding the releases of microplastics into the aqueous environment via discharges from washing, drying and laundering clothing (Wang et al., 2023), there is a clear gap in the evidence pertaining to microplastic sources and concentrations in air, and awareness of these throughout society (Garcia-Vazquez and Garcia-Ael, 2021). This curtails the ability to improve industry practices and develop new, fit-for-purpose regulation. A significant proportion of the identified synthetic fibrous airborne microplastics may originate from domestic sources, with recent studies suggesting that residential environments may have some of the highest indoor microplastic concentrations (Zhu et al., 2022). Behaviour and care for clothing and, consequently microplastic and microfibre release, may also vary both geographically and culturally (Laitala et al., 2020). Furthermore, homes are well known for experiencing higher concentrations of pollutants (such as PM_{10}) than outdoors (Saramak, 2019) and contribute to the wider environment through the poorly understood indoor–outdoor air quality interface, suggesting the high likelihood of microplastics exhibiting the same trends. This is of particular concern given the large variety of microplastic sources within homes; for example, fashion and clothing which accounts for 75% of all textiles sold in the UK (Textiles Market Situation Report 2019 | WRAP, 2019). When washed, clothing may release 640,000–1,500,000 fibres per kg of washed clothing, each up to 660 μm in length (De Falco et al., 2019). The proportion of microfibres released to air is also thought to be in equivalent concentrations to those released into water (De Falco et al., 2020).

As noted above, individual behaviour has a significant impact on microplastic and microfibre release. With the potential human health effects of inhaling microplastics emerging, quantifying the abundance of these particles in indoor air is important. Whilst some studies (Jenner et al., 2021; Soltani et al., 2021) have done so in a limited number of households, more widespread measurements are logistically difficult and expensive. To gather these data from a cross-section of society, simple and accessible sampling methods are required to facilitate citizen participation in data collection.

The role of citizens in airborne microplastic research

Citizen science, a broad and much-debated term with varied disciplinary, cultural and geographic definitions (Haklay et al., 2021; Ellwood et al., 2023) has been utilised across many disciplines to aid in the generation and measurement of data, from biological invasions (Encarnação et al., 2021) to collecting data on empty houses (Albert, 2021). Whilst no firm agreement has been made on an alternative term, and acknowledging the broader debate around the term, "citizen science" is used herein.

The quality of data generated by citizen scientists can, in some circumstances, be equivalent to that of professionally gathered data (Canfield et al., 2002; Oldekop et al., 2011); as demonstrated by Aceves-Bueno et al. (2017)), between 51 and 62% of citizen science projects generated data that are considered to be accurate from a scientific perspective. Citizens' participation in microplastic research, particularly across wide geographic ranges, is proven to be a viable and valuable means of gathering microplastic measurements whether through structured (Jones et al., 2022) or semi-structured (Paradinas et al., 2021) sampling protocols, allowing new insights into the distribution and composition of microplastics which otherwise would be prohibitively expensive using standard research methods. Applying this approach to science in microplastics research could provide similarly valuable insights into the sources of airborne microplastics and sensitivity to individual behaviour, and may be robust enough to inform future industrial and governmental policy perspectives.

In light of the emerging evidence of inhaled microplastics impacting human health and of the WHO calling for further research into microplastics (WHO Calls for More Research into Microplastics and a Crackdown on Plastic Pollution, 2019), there is a need to tackle the pressing challenge of investigating airborne microplastics in domestic settings. To do this effectively at scale requires community and citizen buy-in, often explored and delivered in other aligned fields through citizen science approaches (Oturai et al., 2021; Varaden et al., 2021), both raising people's awareness of a given topic and gathering valuable data.

To date, few studies have looked at the intricacies of the prevalence of indoor microplastics or the link between indoor microplastics exposure and behavioural and regulatory approaches that could reduce their concentrations. The application of a quintuple innovation helix, a model that proposes five interconnected and complementary dimensions (Government, Industry, Academia, Civil Society and Individuals) for fostering innovation and development in a knowledge-based society (e.g., Carayannis et al., 2012), can address this important gap in microplastics research. This framework has the potential to underpin participatory citizen science methodologies to enable a step-change in the volume of data gathered on airborne microplastics concentrations indoors through subject knowledge transfer, method development, data collection and subsequent policy development. This allows for the creation of new insights into the behaviours and decision-making processes that are linked to the generation and reduction of indoor concentrations. Furthermore, participatory projects underpinned by a quintuple helix framework would offer the opportunity to involve industries and governments (tailored to different countries and contexts) in thinking about short-term interventions and long-term policies, strategies and practices aimed at tackling this emerging environmental and health challenge.

Airborne microplastic measurement has, until now, been the domain of environmental scientists. Samples have been collected primarily outdoors using both active (Trainic et al., 2020) and passive sampling methods (Wright et al., 2020), whilst few studies have sought to investigate the indoor environment (Dris et al., 2017; Vianello et al., 2019; Gaston et al., 2020; Jenner et al., 2021). Of these indoor studies, Jenner et al. (2021) undertook the broadest indoor assessment, measuring deposited microplastics across 20 households using beakers as collection methods with all sampling and analysis undertaken by the researcher. Jenner et al. (2021) also identified a potential relationship between clothing behaviour and microplastic prevalence. However, these initial studies of airborne microplastics have used a range of different collection techniques and sampling intervals that all rely on expensive sampling kits or scientists spending time "in the field," which may reduce the spatial and temporal sampling resolution. Furthermore, the analytical techniques required to characterise microplastics in samples are complex and time-consuming and require consideration of in-field and laboratory controls (Prata et al., 2020). As such, techniques suitable and accessible for citizens should be developed which facilitate the collection and analysis of airborne microplastics by citizens, acknowledge experiential barriers that obstruct participation and reduce opportunities for contamination as far as practicable.

It should be noted that, although citizen science can provide a means for participants to engage in the scientific process, participation can still be limited for many through a range of experiential barriers, whether these barriers be motivational or technological, or otherwise, in nature (Asingizwe et al., 2020). Introducing a co-creation step in the development of such projects may enable greater access to participation and consequently a richer source of data.

The role of co-creation within microplastics research and policy development

Employing a citizen science research methodology provides an opportunity for citizens to be at the heart of an emerging field, generating data that will underpin future studies and providing source apportionment data – a sought-after commodity in airborne microplastics research (WHO Calls for More Research into Microplastics and a Crackdown on Plastic Pollution, 2019). Citizen science has been used once with airborne microplastic sampling in mind (Soltani et al., 2021). Whilst Soltani et al. (2021) collected 32 samples from an unknown number of households, a citizen science approach is particularly well suited to the collection of larger sample sizes. Similarly, through the citizen science approach, "real life" home environments can be studied, with inhabitants uniquely placed to both carry out and guide the research and provide new insight into the potential exposure of citizens to the inhalation of such particles. Without citizen scientists, extensive research projects investigating indoor domestic environments would be unviable, hence the real need for citizens to sit at the heart of such studies.

Moreover, citizen involvement can help shape the scientific method, enabling citizen-led co-creation of methods to ensure that future participants have a process designed by the citizen, for the citizen. Co-creation as a term has many definitions, dependent on its field of application. For example, within the ecological economics field, Herrmann-Pillath (2020) describes it as an "*emergence of novelty in co-evolutionary processes in which humans play a pivotal role, across various domains, such that intentional activities interact with domain-specific evolutionary dynamics.*" Through a governance lens, Wyborn (2015) describes it as a tool that "*highlights the social and political processes through which science, policy, and practice co-evolve.*" Within airborne microplastics research, we define co-creation as a transdisciplinary partnership elucidating concentrations and distributions of airborne microplastics and a partnership of knowledge exchange. Some co-created platforms are widely known, for example, the iNaturalist app, an established online platform for users sharing biodiversity information, the citizen science data from which has been used in many publications (Lanner et al., 2020; Durso et al., 2021; Putman et al., 2021). In providing citizens with the opportunity to shape the research tools, it allows for a method that is most suitable for citizens to apply.

Co-creating industry outputs and recommendations for practice and behaviour change with citizens, scientists and industry can also help shape the textile industry's understanding of their contribution to airborne microplastics. This can supplement the evidence derived from microplastic releases into the marine environment and potentially improve the sustainability of products (Henry et al., 2019). This allows for a deeper yet novel understanding of the behavioural root of the microplastics problem and of citizens' perspectives, which are important if society is to effectively tackle this issue and reduce the potential environmental and health impacts of microplastics (Garcia-Vazquez and Garcia-Ael, 2021). This dialogue can leverage the full potential of citizen science to drive bottom-up change and can empower community members to move from issues to actions, as has been explored in other fields (Long et al., 2019; Criscuolo et al., 2023). A co-creative citizen science approach has additional benefits beyond the research itself. It provides citizens with the research skills, knowledge and empowerment to make and advocate for change (Johnson et al., 2014), and the research team with insights into perspectives, such as the lived experience of participants, typically considered to be downstream of the science.

Conclusion

Understanding the presence, distribution and concentration of airborne microplastics is important for untangling our impact on the environment and our personal exposure. In addition, addressing all complexities of the microplastics regulatory gap is challenging (see, e.g., Mitrano and Wohlleben, 2020), in particular when considering the substitution of synthetic fibres for natural fibres, as their presence in the environment and subsequent direct impacts on health and the environment are poorly understood. Nonetheless, this more nuanced understanding of pathways, priorities, potential solutions and key actors and processes, as considered within the quintuple helix framework, is a fundamental first step in the journey towards developing recommendations for new evidence-informed regulation which, thus far, has been lacking. Citizens, in the broadest sense of the term, can play a key role in this through participating in data collection, co-creating participatory and analytical methods, and vocalising barriers to and opportunities for such interactions, which can inform changes to both industry and regulatory frameworks. Future studies should consider the importance of citizen inclusion when designing research strategies for measuring microplastics in domestic settings, enabling a nuanced understanding of microplastic generation and distribution in homes to inform the development of appropriate behavioural and regulatory messaging and measures.

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