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How do plastics, including microplastics and plastic-associated chemicals, affect human health?

Plastics have become deeply integrated into human society and the economy but are polluting the environment. Plastic-associated chemicals enter the human body, and there are also reports of micro- and nanoplastics (MNPs) in human organs[1,2]. There is already a considerable and robust body of evidence on the adverse health impacts of plastic-associated chemicals[3], including those in MNPs, and therefore an urgent public health need to develop and implement comprehensive global measures to protect public and planetary health from plastics. Important policy recommendations grounded in this existing knowledge have recently been formulated[2,4]. If adopted, such policies will see, for example, the elimination of hazardous plastic-associated chemicals, banning of MNPs in personal care products, and increased production and use of sustainable plastic materials with reduced chemical complexity, resulting in greatly improved human and environmental health.

Plastics are composed of a polymer backbone compounded with chemical additives such as plasticizers, flame retardants, stabilizers and colorants, as well as a complex and poorly understood array of non-intentionally added substances. Most of these chemicals are not covalently bound to the polymer matrix and hence are able to leach from plastics, including during intended use of the product and from MNPs[2]. Exposure to plastic-associated chemicals occurs throughout an individual's lifespan, starting before conception, and these chemicals are consistently detected in human biosamples during pregnancy, at birth, in children and in adults[1–3]. A recent report revealed that there are over 16,000 plastic-associated chemicals, of which 6,300 have high exposure potential, including more than 1,500 that are known to leach from plastics[4]. Although extensive data exist on the negative health impacts of certain plastic-associated chemicals and chemical groups[1], a staggering 66% of plastic-associated chemicals do not have available hazard data, and of those that do, more than 4,200 (around 75%) are already known to be hazardous to human and/or environmental health[4]. For example, phthalates and bisphenol A are known endocrine disruptors and have been associated with multiple health impacts at current levels of exposure in the general population, including type 2 diabetes in adults and developmental changes in newborns[1–3].

The absence of data on both exposure and health risks from exposure to most plastic-associated chemicals should not be misconstrued as an indication of safety. Additionally, there is limited understanding of the toxicity of complex real-world mixtures of plastic-associated chemicals[1]. A recent study found that a single plastic food packaging article can contain thousands of chemical features, and that this chemical cocktail activates cell receptors associated with endocrine and metabolic disruption, whereas plastic articles with fewer chemical features induce less toxicity[5]. Increased commitment by governments to prioritize research on plastic-associated chemicals, in addition to MNPs, is urgently required. Although there is already sufficient evidence to warrant immediate policy changes, further research is needed to support that response through improved surveillance of exposure and additional, previously unanticipated harms, thereby better protecting human health.

Understanding the full range of human health hazard and impacts of MNPs has been challenging, primarily because of measurement difficulties. Although there are well-established and standardized techniques to accurately detect and quantify the levels of many plastic-associated chemicals to which humans are exposed, the same cannot be said for small plastic particles[1]. The techniques for measuring MNPs in complex human biosamples are still in the early stages of development. Studies conducted thus far have been challenged by contamination issues[6] and by interferences from matrix components, such as lipids[7]. Concerted efforts are being made to identify suitable measurement technologies and develop standardized measurement techniques to address these issues[1]. This includes the development of purpose-built laboratories to prevent contamination[8] and a much-needed framework for reporting confidence in the analytical data being reported. Together, these developments will pave the way for precise measures of internal exposure that are necessary to quantify the health impacts of MNPs.

The Global Plastic Treaty, now in the final stages of negotiation, is an ideal opportunity for an international and legally binding instrument to address plastic pollution and mitigate human health impacts[2]. Plastic-associated chemicals and polymers of concern are included in the Revised Zero Draft text[9], and we applaud the work of the Scientists' Coalition for an Effective Plastics Treaty in submitting evidence-based materials, including practical recommendations in relation to both the chemical and particulate facets of plastics across their life cycles, that, if adopted, will result in meaningful reductions in the global impact of plastics on public and planetary health.

Since the third session of the Intergovernmental Negotiating Committee (INC-3), increased alignment was seen at INC-4 in some key areas of negotiation, and importantly, countries agreed to conduct formal intersessional work prior to INC-5, pivotal for progressing relevant discussions and ensuring negotiators arrive at INC-5 prepared to negotiate and finalize the Treaty[10]. Unfortunately, at the conclusion of INC-4, major disagreements continued, including on important matters such as whether the Treaty should include upstream measures to reduce the production of primary fossil fuel–based plastic polymers, whether plastic products and chemicals of concern should be regulated via criterion- or non-criterion-based approaches, whether these regulations should be implemented via globally binding provisions or nationally determined measures, and whether the Treaty should tackle problematic and avoidable plastic products such as short-lived and

single-use plastic products and intentionally added microplastics[10]. The intersessional work will be crucial to further explore these issues and secure a strong outcome of negotiations at INC-5.

The international organization Health Care Without Harm has urged country delegates and the INC to commit to a highly ambitious Treaty that is just, equitable and respectful of human rights by limiting virgin plastic production, eliminating unnecessary plastic products and hazardous plastic-associated chemicals, and ensuring transparency and traceability of chemicals in plastic products and materials. This is expressed via an open letter being signed by over 800 health professionals and over 70 health associations, health care facilities and systems, and supporting organizations.

The response to the adverse health effects of plastics must be comprehensive in scope, including a consideration of plastic-associated chemicals and their mixture effects as well as MNPs.

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References

1. Seewoo, B. J. et al. *Environ. Int.* **181**, 108225 (2023).
2. Landrigan, P. J. et al. *Ann. Glob. Health* **89**, 23 (2023).
3. Symeonides, C. et al. *Ann. Glob. Health* **90**, 52 (2024).
4. Wagner, M. et al. *Zenodo* https://doi.org/10.5281/zenodo.10701706 (2024).
5. Stevens, S. et al. *Environ. Sci. Technol.* **58**, 4859–4871 (2024).
6. Skåre, J. U. et al. *Microplastics; Occurrence, Levels and Implications for Environment and Human Health Related to Food* VKM report 16 https://go.nature.com/3MPRVvN (2019).
7. Rauert, C., Pan, Y., Okoffo, E. D., O'Brien, J. W. & Thomas, K. V. *J. Environ. Expo. Assess.* **1**, 13 (2022).
8. Rauert, C. et al. *J. Hazard. Mater.* **468**, 133803 (2024).
9. UNEP. *Revised Draft Text of the International Legally Binding Instrument on Plastic Pollution, Including in the Marine Environment;* https://go.nature.com/3MRb7Jl (2023).
10. *Earth Negotiations Bulletin* Vol 36, no. 27; https://go.nature.com/3ZC7dvP (2024).

Competing interests

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