Plastics, plastic chemicals, and microplastics: multiple harms to health

Microplastics and nanoplastics (MNPs) are everywhere. These tiny particles—formed by abrasion, fragmentation, and open burning of plastics—are found in the ocean, the Arctic, Himalayan glaciers, air, food, and drinking water.[1] More recently, they have been reported in human lung and faeces, reflecting exposures via inhalation and ingestion, as well as in blood, carotid arteries, heart, brain, liver, ovaries, testes, and placenta.[2] Early clinical and epidemiological reports suggest associations between MNPs and health effects, notably cardiovascular disease, adverse reproductive outcomes, and immune modulation.[2,3] These findings are supported by experimental models showing that MNPs, especially smaller particles, can cross epithelial barriers to induce inflammation, oxidative stress, and metabolic disruption.[2] These reports have received considerable attention.

Critics argue that reports identifying MNPs in tissues and linking MNPs to disease are flawed.[4] Such debate should not be misinterpreted. Debate is a healthy part of the inherently iterative and incremental nature of new scientific discovery for which uncertainties are expected, assessed, and repeatedly retested. In no way does it mean that MNPs are not present in human tissues or signal that their presence is benign or can be ignored. Nor does it suggest that recently reported associations between MNPs and disease[2,3] can be dismissed. Instead, these discussions highlight the need to develop robust, selective, and sensitive analytical methods that can reliably and accurately generate data on the types, quantities, and locations of MNPs in tissues and thus confidently advance understanding of MNPs' risks to health.[5]

A framework proposed to achieve this goal is to combine the two complementary, orthogonal techniques currently used for plastic particle analysis: particle-based methods that provide data on MNP size, morphology, and spatial distribution but can only evaluate chemical composition for larger microplastics; and mass-based approaches that provide information on chemical composition and quantity (panel).[5,6] Developing and validating this combined framework is a crucial priority that is best advanced through an interdisciplinary, international working group.[5]

Beyond MNPs, there is strong evidence that plastics harm human and planetary health at every stage of their lifecycle. Disease and premature deaths occur in the extraction of fossil fuels from which plastics are made, as well as in primary plastic production, product manufacture, transport, product use, recycling, open burning, and waste management.[7] Environmental degradation also occurs at every stage, resulting in pollution of land, air, water, and the ocean.[7] These harms are global but unevenly distributed. They exacerbate social and environmental injustices.[8] Pregnant women, children, workers, and communities near fracking sites, oil wells, pipelines, railways, production and recycling facilities, and waste disposal sites are at disproportionate risk.[7,8] With global plastic output projected to triple by 2060, these harms are worsening.[9]

Many of plastics' established health impacts are due to the more than 16 000 chemicals in plastics.[10] These include known carcinogens, neurotoxicants, and endocrine disruptors such as phthalates, bisphenols, brominated flame retardants, and perfluorinated and polyfluorinated substances. These chemicals can comprise up to 70% of plastics by weight. Because most are not chemically bound to polymers, they leach out of plastics, enter tissues and cells, and are associated with disease and death at all ages.[11] MNPs can carry plastic chemicals into the human body.

In infants and children, plastic chemicals increase risks of prematurity, stillbirth, low birthweight, birth

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Panel: Analytical techniques for MNPs

Current analyses of microplastics and nanoplastics (MNPs) in tissues and body fluids rely on two complementary, orthogonal approaches.

- Particle-based methods, including electron microscopy, laser-directed infrared spectroscopy, Fourier transform infrared spectroscopy, and Raman spectroscopy. These provide information on individual particle sizes, morphology, abundance, and spatial distribution, but can evaluate chemical composition only for larger microplastics.
- Mass-based approaches such as pyrolysis-gas chromatography and mass spectrometry. These identify chemical composition of polymers and quantify polymer mass, but cannot provide information on particle morphology, size, or location.[6]

Because neither approach alone enables both definitive morphological assessment and chemical characterisation of MNPs in biological matrices, an analytical framework has been proposed that combines data from these two complementary techniques.[5] Similar complementary analytical frameworks are used in forensic science.

defects, and neurodevelopmental disorders.[11] In adults, they increase risk of obesity, diabetes, hypertension, cardiovascular disease, lymphoma, and decreased fertility.[11] National biomonitoring surveys find multiple plastic chemicals in the bodies of nearly all people surveyed. The annual costs of the health impacts of a few well studied plastic chemicals are conservatively estimated at US$1·5 trillion.[12]

Plastics additionally harm health by accelerating climate change. In 2019, plastic production generated 2·24 gigatonnes of carbon dioxide equivalent, 5·3% of all global greenhouse gas emissions.[13] The estimated annual global costs of disease and death attributable to these emissions exceed $340 billion.[7]

Going forward, epidemiological, toxicological, and mechanistic research to close gaps in knowledge and further elucidate plastics' harms to health will be essential. This research could include prospective, multiyear studies of infants exposed in utero to plastic chemicals,[14] investigations of chemical mixtures and their effects on metabolism and gene expression,[15] and studies of MNPs' health impacts using new, combined analytical strategies.[5]

The priority for public health is to act on current evidence of plastics' harms to health and take scientifically informed, precautionary action to prevent disease and premature death across every stage of the plastic lifecycle, even as research proceeds. Experience with tobacco, asbestos, and lead has shown the grave danger of ignoring early warnings, succumbing to industry-manufactured doubt,[16] and delaying reasonable intervention.

The recently launched *Lancet* Countdown on Health and Plastics will be key.[17] By tracking and regularly reporting on a suite of scientifically meaningful and geographically and temporally representative indicators across all stages of the plastic lifecycle, the *Lancet* Countdown will quantify plastics' harms to health, count their contribution to the Global Burden of Disease, and inform interventions. It will identify areas in which new knowledge is needed. It will monitor the roll-out of measures to mitigate harm. This Countdown is inspired and modelled on the *Lancet* Countdown on Health and Climate Change that has been an independent, science-based voice of accountability for the past decade, and has been highly effective at centring health in the climate conversation.[18]

Interventions to prevent plastics' harms must take place at all levels. The global plastics treaty[19] now being negotiated by UN member states has potential to effectively coordinate ambitious international action. This treaty must address health and environmental impacts across the full plastics lifecycle, be informed by scientific evidence, and be capable of evolving in response to new evidence. To date, a small, but powerful bloc of largely petroleum-producing nations has opposed inclusion of upstream provisions limiting plastic production and addressing plastic chemicals, both of which would protect health.[20] In the reinvigorated treaty process under a newly elected chair, it will be crucial to advance a draft that responds to the call of more than 100 UN member states for a treaty that safeguards human and planetary health and encompasses the entire plastics lifecycle. Addressing chemicals of concern in plastics will be critically important.

Local and national interventions are also necessary. Important measures include elimination of unnecessary plastics (including in health care), improved management of plastic chemicals and plastic waste, and introduction of safer plastics not based on fossil fuels.[21]

Doctors, nurses, researchers, and all health professionals can make important contributions to reducing plastics' harms. Health professionals need first to recognise that plastics and plastic chemicals are emerging threats to human and planetary health whose multiple harms are only beginning to be measured. They can educate their colleagues, their patients, and policy makers about these hazards, urge plastic use reduction in health-care systems, and call for transition to safer materials. And as they are doing with climate change, health professionals can raise their trusted voices and speak truth to power on behalf of their patients.

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