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Human health impacts of plastic exposure – an evolving evidence base

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Summary

The evidence for harm to human health caused by plastic has grown in the last five years, notably from chemical additives in plastics and plastic particles themselves. This evidence strengthens the case for urgent action to prevent further plastic pollution, remediate environments containing plastic, reduce our interactions with plastics in our day-to-day lives, and minimise exposure to plastic particles[i] where possible. While individual actions are helpful, we need systematic change at the local, national, and global levels to achieve a comprehensive response to the environmental and health threats from plastics.

Introduction

In 2019, the authors were part of an expert panel advising PM Ardern on how to address the wicked problem of plastic pollution.[1] The evidence base for environmental harm caused by plastic was incontrovertible and provided a compelling case for urgent action.[2] The evidence base for the human health impacts of plastics was less developed[1] but it was clear that more research was needed into the human health impacts of both the chemicals added during plastic manufacture and of plastic particles themselves (micro[i]- and nanoplastics[ii]). Since then, the evidence base for harm to human health has strengthened.[3]

Plastics[ii] were initially regarded as inert materials, an assumption that underpins their near ubiquitous use. Increasingly, this assumption is challenged. Risks to human health are associated with plastic exposure due to intertwined chemical, physical, and biological hazards, which are considered here in turn.[iii]

Plastic-associated chemicals

Around 16,000 chemicals are associated with plastic products, from synthesis to manufacture of the final product, with many found in significant quantities in the finished products.[4] These chemicals are not bound and may migrate out of the material over time. About a quarter of these chemicals are known to pose a risk,[5] and for others the risk is unknown because of a lack of toxicological data.

Chemicals can leach from plastic items in different environments, e.g. food contact chemicals can leach from plastic packaging into food that is in contact with these materials.[6,7] There are also many everyday examples of direct exposure through skin.[8,9] In general, the risks of chemical contamination from plastic materials increase as the plastic degrades.[10] Risks to human health caused by plastic particles and associated chemicals include potential carcinogenic, developmental, and endocrine disrupting impacts.[11] For example, a recent study provides preliminary evidence of an association between pre-natal exposure to BPA and autism.[12]

Plastic particles

Plastic particles may be used in manufactured products or be released from plastic items during use, inevitably resulting in inhalation and ingestion,[13] including from our water and food.[14] In Aotearoa New Zealand (NZ), plastic particles have been recorded in fresh produce, such as seafood, and processed foods, including beverages.[15] We do not yet know the extent to which they occur in our drinking water, but overseas these particles have been located in source waters, as well as in tap and bottled water.[16,17] In California, there is now legislation for source waters to be tested.[18]

Plastic particles pose a risk via their physical presence. Physical attributes such as their shape (e.g. sharp-edged fragments or needle-like fibres) and charged surfaces increase the likelihood of cellular interaction and damage.[14] There is also increased probability of release of associated chemicals used in plastic manufacture (see above) from the high surface area of the particles, and risk associated with microbes that may have colonised the plastic surfaces (see below).

There is insufficient information to draw firm conclusions on the toxicity related to plastic particles, but growing evidence, especially from animal models, points to the likelihood of harm.[19,20] There is high variability[21] in the amount of plastic particles to which humans are exposed in water, food and air.[22,iv] Plastic particles are unlikely to cross the skin,[22] but if small enough can generally translocate from the gastrointestinal tract and respiratory systems to other tissues.

Evidence of internalisation into the human body continues to mount, with reports that plastic particles have been found in human lung,[23,24] liver,[25] bowel,[26] brain,[27,v] breastmilk,[28] placenta,[29] blood,[30,31] uterus[32] and the endometrium.[33,vi] Although current methods of identification of these tiny particles in tissue samples pose several analytical challenges,[vii] it is known that plastic of specific particle sizes are internalised by tissues and organs in animals.[34,viii] Knowledge of the potential impacts of this internalisation on humans remains in its infancy, but includes carcinogenicity,[35] genotoxicity, cell division and viability, cytotoxicity, oxidative stress induction, metabolism disruption, DNA damage, IBS,[36] inflammation, immunological responses and reproductive health risks.[37-40]

Microbials

The influence of plastic particles on microbiological health risks is an emerging area of understanding. There are suggestions that the biofilms growing on the surface of plastic in the environment increases the risk of microplastic uptake,[41] infectious disease,[42] disrupted microbiomes[43,44] and antimicrobial resistance.[45]

Outlook

As highlighted in an excellent recent review of microplastics pollution,[46] there is now ‘extensive evidence of substantial widescale environmental accumulation …[and] … toxicological effects have been confirmed across all levels of biological organization.’ The evidence for potential effects on human health is growing, and along with it the need for a policy response.[46] As we outlined in our 2019 report,[1] while individual behaviour choices can be helpful, system-wide change is required to reduce plastic use and remove plastic from the environment. Our growing understanding of human health impacts adds urgency to the need for these changes and underpins the importance of minimising our day-to-day exposure to plastics. The UN Plastic Pollution Treaty presents an international opportunity for action.[47,48]

What this briefing adds

- There is strengthening evidence of human health harm from plastic-associated chemicals and their exposure pathways, with the risk not restricted to the end of a product's life.
- There is strengthening evidence for human health impacts of plastic particles, which remains uncertain, but continues to grow.
- There is a strong case for urgent action to reduce plastic use and plastic pollution globally.

Implications for policy and practice[ix]

- NZ should continue to take steps to reduce plastic use and plastic pollution, maintaining momentum and monitoring the success of policy changes made since 2019.[2]
- NZ needs to improve our understanding of plastic exposure risk, and take mitigation steps to reduce the risk across the whole life cycle of plastic products.
- NZ should maintain a watching brief on the hazards of exposure to food contact chemicals.[7]
- NZ should support global efforts in this arena, by advocating for an evidence-based UN Global Plastics Treaty.[47,48]

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Endnotes

i. We use the term plastic particles to incorporate both microplastics (small plastic pieces less than five millimetres long) and nanoplastics (very small plastic pieces, <1 µm (1000 nm))

ii Plastics are defined here to include the base polymer additives included in manufacture of the finished materials or products.

iii. Other sources of exposure including occupational exposure, for example for workers at manufacturing and recycling plants and in textile factories, and the specific hazards caused by open burning of plastics, more common overseas, are out of scope of this short briefing.

iv. This review contains a useful discussion of some concerns expressed by the scientific community on the methodological approaches used, and quality of analysis undertaken in, some of the studies published on micro- and nanoplastics exposure and impacts on human health. There is consensus on the potential routes of exposure of plastic particles, and a strong body of evidence from animal studies showing the translocation of particles within the body, and potential impacts. The studies reviewed here lay the foundation for future research that is expected to expand and improve upon current methods used for human samples, as well as understand the mechanisms of toxic action of plastic particles.

v. Noting that this paper is in pre-print only and that some of the methodology used may be contested.

vi. The authors mention chewing gum as a source, an under-appreciated route of plastic exposure.

vii. For example, due to the ubiquity of plastic particles in the environment there is a high risk of contamination during sample collection, processing and analysis. Strict contamination control measures, including the use of blanks at each stage, are essential to ensure the accuracy and reliability of studies. This becomes more challenging the smaller the particle size of interest. There is consensus that methods need to be improved and on the need for standardised methodology that is reliable and includes all required QA/QC. See e.g.: Sharma, P, Sharma, P, Abhishek, K. Sampling, separation, and characterization methodology for quantification of microplastic from the environment. *Journal of Hazardous Materials Advances* 2024;14: 100416. doi:10.1016/j.hazadv.2024.100416; Dong, H, Wang, X, Niu, X, Zeng, J, Zhou, Y, Suona, Z, Yuan, Y, Chen, X. Overview of analytical methods for the determination of microplastics: Current status and trends. *Trends in Analytical Chemistry* 2023;167: 117261. doi:10.1016/j.trac.2023.117261; Ivleva, NP. Chemical analysis of microplastics and nanoplastics: Challenges, advanced methods, and perspectives. *Chemical Reviews* 2021; 121(19): 11886-11936. doi:10.1021/acs.chemrev.1c00178

viii. Caution needs to be taken with any studies that have used py-GC/MS for the identification of NMPs in samples; there has been a lot of scrutiny over whether the methods and/or analysis used for such studies are sufficiently rigorous (see vii).

ix. Although out of scope for this briefing, Aotearoa New Zealand should also cease export of plastic waste to countries without the infrastructure to deal with it safely.

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