Why Detecting Nanoplastics in Humans Matters: Exposure Routes, Biological Evidence, and Potential Health Implications

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Abstract:

Nanoplastics, defined as plastic particles smaller than one micrometre, have emerged as a growing concern in human health research. Their small size allows them to cross biological barriers and interact directly with cells and tissues. Recent studies have confirmed the presence of plastic particles in multiple human biological matrices, including blood, lung tissue, placenta, faeces, urine, vascular tissue and brain samples. These findings indicate that human exposure to nanoplastics is not merely environmental but involves internal uptake.

This review summarises current evidence on routes of human exposure and biological matrices, where nanoplastics have been detected, and potential health implications, on the basis of experimental and emerging clinical data. Ingestion and inhalation appear to be the dominant exposure pathways, with additional concern related to maternal-foetal transfer. Experimental studies suggest that nanoplastics may induce oxidative stress, inflammation, endocrine disruption and neurobiological effects, although direct causal links in humans remain limited.

Accurate detection in clinical samples is essential for risk assessment and future epidemiological studies. While techniques such as pyrolysis gas chromatography–mass spectrometry (GC–MS), Raman spectroscopy, and single-particle inductively coupled plasma mass spectrometry (ICP–MS) have enabled recent discoveries, methodological limitations persist. Standardisation of analytical workflows is required before routine clinical interpretation can be achieved.

Key words: Nanoplastics, Microplastics, Human Exposure, Blood-Brain Barrier, Inhalation, Ingestion, Public Health, Environmental Pollutants.

Introduction

Plastics are widely used in healthcare, food packaging, textiles and day-to-day consumer products due to their durability and low cost. The physical and chemical degradation of plastic materials leads to the formation of progressively smaller fragments.[1,2] While microplastics have been extensively studied, attention has increasingly shifted toward nanoplastics because of their greater biological accessibility.[3,4]

Nanoplastics occupy a size range comparable to viruses and macromolecular complexes.[4] These properties enable interactions with cellular membranes and facilitate translocation across epithelial barriers.[3,5] As a result, nanoplastics may access tissues that are typically protected from particulate exposure, including the placenta and central nervous system.[6,7]

Over the past several years, multiple independent studies have confirmed the presence of plastic particles in human biological samples.[8-10] Detection in blood, lung tissue, placental tissue, faeces, urine, vascular specimens, and brain tissue has shifted the discussion of plastic exposure from an environmental issue to a clinical and public health concern. [6-7,11-13] Understanding how nanoplastics enter the body, where they accumulate and what effects they may exert is now relevant to medical research.[1,14]

Routes of Human Exposure

Ingestion

Dietary intake is considered the primary route of exposure to nanoplastics.[2] Plastic particles have been identified in drinking water, bottled beverages, seafood, salt and packaged foods.[2,5] Food processing and packaging practices further contribute, particularly when plastics are heated or mechanically stressed.[3]

Once ingested, nanoplastics encounter digestive enzymes and bile salts that alter particle surface properties.[3,4] Experimental models suggest that these particles can cross the intestinal epithelium through cellular uptake or paracellular transport.[1,5] After translocation, particles may enter systemic circulation and distribute to internal organs.[14]

Inhalation

Inhalation represents a second major exposure route.[9] Airborne nanoplastics originate from sources such as synthetic textiles, traffic-related emissions, industrial activity and indoor dust.[5] Due to their small size, these particles can reach the distal airways and alveoli.[9]

Human lung tissue analyses have identified common polymers, including polyethylene and polypropylene.[9] Clearance mechanisms appear limited, and retained particles may trigger local inflammatory responses or translocate into the bloodstream.[1]

Dermal exposure (skin exposure)

The skin functions as an effective barrier, but nanoscale materials may penetrate under certain conditions, particularly with repeated exposure or barrier disruption.[4] Nanoplastics are present in some cosmetic and personal-care products.[3] While systemic uptake via the skin is likely limited, localised effects and occupational exposure remain areas of concern.[5]

Maternal–foetal transfer

Detection of plastic particles in human placental tissue indicates that nanoplastics can cross the placental barrier.[6] This finding raises concern regarding prenatal exposure during critical periods of development.[1,6] Although clinical consequences have not yet been established in humans, animal studies suggest potential developmental effects.[3,14]

Biological Evidence of Nanoplastics in Humans

Nanoplastics and related microplastics have been detected in a growing range of human biological matrices.[1,10] Blood was among the first tissues studied, providing evidence of systemic distribution.[8,10] Placental detection supports the possibility of foetal exposure,[6] while lung tissue findings confirm inhalation as a relevant route.[9]

Faecal samples indicate widespread dietary exposure, though they do not distinguish between absorbed and excreted particles.[15] More recent studies reporting plastic particles in urine, vascular tissue, thrombi, joints, semen, and brain samples suggest that some particles may persist or accumulate in the body.[7,11,16] Microplastics have also been detected in human lower limb joint tissues and saphenous vein samples, further supporting systemic distribution and tissue deposition.[17,18] Identification of plastic particles in brain tissue is of particular concern, as it may reflect passage through or alteration of blood-brain barrier integrity.[7]

Potential Health Implications

Direct clinical evidence linking nanoplastics to disease in humans is currently limited.[1] However, experimental studies provide insight into possible biological effects. Cellular uptake of nanoplastics has been associated with oxidative stress, mitochondrial dysfunction and inflammatory signalling.[3-4,14]

Immune activation following particle exposure may result in chronic low-grade inflammation, a process implicated in cardiovascular, metabolic and respiratory diseases.[1,5] In addition, plastics often contain chemical additives such as bisphenols and phthalates, which are known endocrine disruptors.[1,3] Nanoplastics may act as carriers for these compounds, enhancing cellular exposure.[14]

Animal studies also suggest potential neurotoxic effects, including neuroinflammation and altered behaviour

following exposure.[3,14] The relevance of these findings to human health requires further investigation, particularly through longitudinal clinical studies.[1]

Clinical and Public Health Relevance

From a medical perspective, detection of nanoplastics in human tissues is a prerequisite for meaningful risk assessment.[1] Without reliable quantitative data, it is not possible to evaluate exposure thresholds, identify high-risk populations, or assess associations with disease outcomes.[5]

Current analytical techniques have enabled important discoveries but are not yet suitable for routine clinical use.[8,19] Challenges include contamination control, limited sensitivity for smaller particles and lack of standardised protocols.[8,10] Harmonisation of detection methods will be essential for future clinical and epidemiological research.[1]

Conclusion

The identification of nanoplastics within human tissues represents a meaningful shift in how plastic pollution is understood in relation to human health. Rather than remaining an abstract environmental issue, plastic exposure has now been shown to extend into the human body itself, confirming that contact with these materials is both direct and ongoing. Current evidence suggests that exposure is common and occurs through everyday activities, particularly through food consumption and breathing contaminated air, with early findings also indicating that exposure may begin before birth via transfer across the placenta.

At present, clear links between nanoplastic exposure and specific diseases in humans have not been firmly established. However, findings from laboratory and animal studies raise reasonable concern. These studies suggest that nanoplastics can enter cells, interfering with normal cellular functions and promoting inflammatory and oxidative processes. Their small size allows them to reach sensitive tissues, and their chemical composition may further contribute to harm by transporting additives or environmental pollutants into the body. While these mechanisms do not yet equate to proven clinical disease, they provide a credible biological basis for potential long-term effects.

Advancing knowledge in this area will require a coordinated research effort. Reliable and standardised methods for detecting nanoplastics are essential to ensure that results are comparable across studies. Equally important are long-term human investigations that can track exposure over time and assess possible associations with health outcomes. Without such data, risk assessment remains incomplete, and uncertainty persists regarding vulnerable populations and safe exposure thresholds.

From a broader medical and public health perspective, nanoplastics should be considered within the context of prevention and environmental risk management. Recognising them as a possible contributor to chronic disease burden encourages early monitoring, informed policy decisions and public awareness. As research progresses, integrating nanoplastic exposure into environmental health assessments may become an important step toward protecting population health and reducing avoidable risks in the future.

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