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Editorial

Placental Exposure to Nanoplastics Threatening the Maternal and Fetal Health

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In an era defined by convenience and mass consumption, plastic has become both a marvel and a menace. While society has reaped the benefits of plastics in healthcare, food safety, and technology, the afterlife of these materials tells a darker story. Once discarded, plastics fragment into microscopic and nanoscale particles nanoplastics (NPs) so small they can cross cellular barriers, enter tissues, and potentially alter biological processes, have emerged as a critical concern. These invisible pollutants are now being detected in human lungs, blood, placenta, and even breast milk, raising urgent questions about long-term health implications for maternal and fetal health during pregnancy. The exposure to NPs during pregnancy raises important considerations for both maternal and fetal well-being, especially amidst the broader challenge of plastic pollution that threatens our environment. With approximately 400.3 million tons of plastics produced in 2022 largely stemming from single-use items that break down into smaller particles NPs have been detected in various ecological settings, including water, air, and the human body.(1)

Nanoplastics are typically defined as plastic particles less than 100 nanometers in size. Unlike their larger counterparts, microplastics (1 μm to 5 mm), nanoplastics can permeate cell membranes and translocate across physiological barriers, including the blood-brain barrier and the placental barrier.(2) These particles arise from the degradation of larger plastics in the environment and are also directly manufactured for industrial use in pharmaceuticals, cosmetics, and food packaging. Because of their nanoscale dimensions and high surface-area-to-volume ratio, nanoplastics exhibit unique physicochemical properties. They are often chemically reactive, capable of binding with heavy metals, persistent organic pollutants (POPs), and other contaminants, potentially enhancing their toxicity. Their surface characteristics such as positive or negative charge and the presence of functional groups can further influence their behavior in biological systems.

The growing prevalence of nanoplastics in our environment underscores the importance of understanding their biological impact, particularly during vulnerable stages like pregnancy. Research has established links between maternal exposure to nanoplastics and various reproductive complications, such as increased risks of miscarriage, premature birth, and long-term metabolic disorders in children, including dyslipidemia and type 2 diabetes. As the presence of nanoplastics increases, it is crucial to focus on their potential biological effects, especially

during sensitive developmental stages like pregnancy and early life. The AURORA project, a five-year research initiative (2021-2026), aims to bridge existing knowledge gaps regarding the risks posed by nanoplastics to human health.[3,4] This research is vital since NPs may exhibit greater biological mobility and bioavailability than larger plastics, allowing them to navigate biological membranes more effectively.

Recent toxicological studies published in the Science of the Total Environment highlight the need for continued research into nanoplastics. Findings reveal that certain types of nanoplastics particularly those with surface modifications can interact with key cellular processes, disrupt gene expression, and activate inflammatory pathways. As the global challenge of nanoplastic contamination grows, it is imperative for the public health community to recognize this emerging concern and take appropriate measures. This editorial advocates for immediate action through concerted efforts in research, regulation, and education to avert an invisible crisis from escalating into a more significant catastrophe.

Winiarska et al. reveal that positively charged polystyrene nanoplastics with amine groups induce greater cytotoxicity and inflammatory gene expression than neutral or negatively charged particles, underscoring their bioactive nature and potential health risks.[5] Emerging evidence shows that nanoplastics can harm human health by triggering oxidative stress and inflammation, disrupting cellular homeostasis, altering gut microbiota, and interfering with hormonal signals. These effects may contribute to chronic diseases, reproductive toxicity, and long-term impacts on future generations.

Despite various findings, many unknowns still linger in the discussion surrounding nanoplastics. Human epidemiological studies remain limited, with most data emerging from animal models or cell cultures that fail to mirror human exposure dynamics or the effects of chronic low doses. Furthermore, our understanding of how nanoplastics interact with other pollutants is still lacking, heightening concerns about potential synergistic toxicity in real-world situations.

While the scientific community is beginning to unravel the toxicological effects of nanoplastics, public health systems and regulatory frameworks lag alarmingly behind. Currently, there are no standardized guidelines from the World Health Organization (WHO), the U.S. Food and Drug Administration (FDA), or other global authorities concerning acceptable levels of nanoplastics in food, water, or air. This regulatory gap is partly attributed to the technical challenges of detecting and quantifying nanoplastics within complex matrices and also stems from a fragmented understanding of their long-term health implications. However, just because regulations are absent, it doesn't mean risks aren't present. Vulnerable populations—including children, pregnant women, and low-income communities near plastic waste processing sites—may face disproportionate exposure. The issue also intersects with environmental justice, as many developing nations bear the greatest burden of global plastic waste without sufficient waste management or pollution monitoring infrastructure. Public health professionals must recognize and address these oversights. We should approach the issue of nanoplastics not just as an environmental concern but as a public health priority, akin to the early recognition of the dangers posed by lead poisoning or air pollution.

To tackle this pressing issue, governments and funding agencies need to prioritize longitudinal human studies that explore nanoplastic exposure and health outcomes. We must enhance biomonitoring efforts by developing standardized methods to identify nanoplastics in biological fluids. Additionally, collaborative toxicological research is needed to examine how nanoplastics interact with other environmental stressors. Environmental and food safety regulations must adapt to categorize nanoplastics as a distinct class of contaminants, and risk assessment protocols should be updated. Policymakers should apply precautionary principles, especially in light of incomplete scientific consensus, and consider clear labeling of products that utilize or release nanoplastics.

Public health campaigns should aim to make the emerging science accessible to the public. Educating consumers about how they might encounter nanoplastics—through single-use plastics, synthetic textiles, and cosmetics—can foster behavioral changes that mitigate risk. Health promotion strategies should emphasize reducing plastic usage, ensuring proper waste disposal, and supporting biodegradable alternatives. Moreover, investing in the creation of eco-friendly materials that are safe to degrade or that will not fragment into nanoplastics is of utmost importance. This endeavor requires collaboration among chemists, engineers, and public health experts to invent sustainable

consumer products that do not compromise human health.

The nanoplastics crisis is no longer a hypothetical issue—it's unfolding in real-time within our environment and alarmingly within our bodies. The study by Sun et al. serves as yet another cautionary tale, illustrating that even the tiniest fragments of our plastic habits may have profoundly harmful biological consequences. We find ourselves navigating uncharted territory where the lines between industrial advancement and planetary health have become blurred. History has shown us, through cases like asbestos, lead, and tobacco, that delaying action in the face of emerging evidence comes at a significant human cost. We must learn from past mistakes and recognize that the time to address nanoplastics is now—before these unseen invaders leave a lasting mark on future generations.

Growing concern over plastic pollution, especially regarding maternal and fetal health, has ignited calls for more thorough research and stringent regulatory measures. Expert assessments and studies on similar pollutants are essential in crafting protective strategies and identifying further research priorities in this field. Recent findings underscore the urgent need to investigate the potential impacts of plastic exposure during pregnancy, particularly regarding its implications for fetal development. One notable study highlighted the presence of high plastic concentrations within the placentas of premature infants, emphasizing the need for a deeper inquiry into how such exposures might influence pregnancy outcomes. As research on micro and nanoplastics (MNPs) and health is still nascent, there's a recognized necessity for actionable risk assessment frameworks focused specifically on MNP exposure in early life. Such frameworks aim to bridge existing knowledge gaps and prioritize evaluations of the impact of MNPs on early-life health, highlighting the need for uniform methodologies to yield valid, reproducible, and comparable research findings.

Ethics Approval

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Competing Interests

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Underlying Data

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