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Literature Review

Understanding the Side Effects of the Plastic Storage Bags Used for Breast Milk and the Environment: A Narrative Review

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ABSTRACT

The widespread use of plastic breastmilk storage bags raises concerns about microplastic (MP) exposure in infants, particularly during storage and heating. This review aimed to summarize evidence on MPs' release from storage bags, infant exposure pathways, potential health effects, and environmental implications. A narrative review was conducted using PubMed, Scopus, ScienceDirect, and Google Scholar for studies published between January 2015 and June 2025. Keywords related to MPs, breast milk, storage bags, and infant exposure were used. Six eligible studies were included. Plastic storage bags can release MPs, especially with heat exposure, prolonged storage, and repeated use. MPs have been detected in breastmilk and infant feces, indicating early-life exposure. Small particles may cross the gastrointestinal barrier, with experimental studies suggesting potential effects such as oxidative stress, inflammation, and microbiota disruption. However, clinical evidence in infants remains limited. In conclusion**,** Breastmilk storage bags may be a modifiable source of infant exposure to MPs. Although clinical impacts are not yet established, safer storage practices and further human studies are needed.

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INTRODUCTION

Breast milk is recognized as the optimal source of nutrition for infants by providing essential nutrients, immunological protection, and bioactive compounds critical for early development. To support breastfeeding practices, especially among working mothers, breast milk storage products, such as plastic storage bags, are widely used due to their convenience, affordability, and portability (Edemba et al., 2022; Szyller et al., 2024).

The increasing use of plastic materials has raised concerns about microplastic (MP) contamination, particularly in food-contact products. (Priya et al., 2022) Plastic production has increased globally, reaching approximately 359 million tons in 2020 (Priya et al., 2023). MPs are defined as plastic particles smaller than 5 mm that originate from the degradation of larger plastic materials or are intentionally manufactured at microscopic sizes (Das et al., 2025). Emerging evidence suggests that food-contact plastics, including breast milk storage bags, may act as a direct source of MPs exposure in humans (Zimmermann et al., 2025).

Plastic breast milk storage bags are typically marketed as single-use, food-grade products. However, practices such as reuse, prolonged storage, and heating breast milk within the plastic bags may increase the release of MP particles into breast milk (Liu et al., 2023). Once ingested, these particles may pose potential health risks to infants, whose immune systems, metabolic pathways, and gastrointestinal barriers are still developing (Nadarasan et al., 2025).

In addition, discarded plastic storage bags may contribute to environmental MPs contamination, which can indirectly influence human exposure through the food chain (Campanale et al., 2020; Osman et al., 2023; Yang et al., 2021). Given the widespread use of these products and the vulnerability of the infant population, it is important to critically evaluate current evidence regarding their safety (Kadac-Czapska et al., 2025).

This narrative review aims to summarize current evidence on the release of MPs from plastic breast milk storage bags, infant exposure pathways, potential health effects, and related environmental implications.

METHOD

This study was conducted as a narrative literature review to explore the potential health and environmental effects of plastic breast milk storage bags, with a particular focus on infant exposure to MPs. A comprehensive literature search was performed using PubMed, Scopus, ScienceDirect, and Google Scholar databases. Eligibility criteria were defined prior to the literature selection process. Studies were included if they were published in English between January 2015 and June 2025 and focused on MPs in breastmilk, infant exposure, or plastic food-contact materials. Eligible study designs included original research articles, experimental studies, and relevant review articles. Studies were excluded if they were not relevant to MPs or infant exposure, or if they were categorized as editorials, commentaries, or conference abstracts. In addition, articles without accessible full text were also excluded from the review.

The search strategy was developed using a combination of keywords and Boolean operators tailored to each database. The primary keywords included “microplastic”, “plastic particles”, “breast milk”, “human milk”, “storage bag”, and “infant exposure”. These terms were combined using Boolean operators (“microplastic” OR “plastic particles”) AND (“breast milk” OR “human milk”) AND (“storage bag” OR “plastic bag”) AND (“infant

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exposure”). Additional relevant studies were identified through manual screening of titles, abstracts, and reference lists.

A total of 10 articles were retrieved from advanced database searches using predefined Boolean strings. Due to the limited retrieval via database search engines, additional articles were identified through manual searching, including citation searching and website searches. After removing duplicates and screening for relevance, 7 articles were included in the final review.

Although this study followed a structured search approach, it remains a narrative review and does not aim to provide exhaustive systematic coverage. However, efforts were made to ensure transparency and reproducibility of the search process.

LITERATURE REVIEW

MPs from Breastmilk Storage Bags

Several experimental studies have reported that plastic breastmilk storage bags can release MPs particles into stored breastmilk. The released particles were primarily identified as fragments and floccules with sizes generally below 300 μm. MP release was found to increase with repeated use of the storage bags and when breastmilk was warmed while still in contact with the plastic. Based on estimated daily breastmilk intake, infant exposure to MPs originating from storage bags ranged between approximately 0.61 and 0.89 mg per day (L. Liu et al., 2023).

MPs Contamination in Human Breastmilk

MPs have been detected in fresh human breast milk, indicating that contamination may occur not only during storage but also through environmental and maternal exposure (Ragusa et al., 2022). Reported concentrations reached up to 2.72 particles per gram of breast milk, with polymer types including polyethylene, polypropylene, and polystyrene. (Chia et al., 2025). Consequently, infants consuming breastmilk may be directly exposed to MPs. Infant intake of MPs occurs primarily through ingestion of contaminated breastmilk and feeding-related products. Studies reported that MPs particles smaller than 2.5 μm are capable of entering the gastrointestinal tract. Experimental evidence suggests that these particles may be absorbed by M cells in Peyer’s patches via endocytosis or via paracellular transport across the intestinal epithelium. This pathway suggests that MPs can cross the gut barrier during early life (Campanale et al., 2020).

Additionally, Saraluck et al. (2024) reported the presence of MPs in 38.98% of human breastmilk samples, with varying polymer compositions. Breastmilk samples containing MPs showed a higher relative abundance of *Staphylococcus* and *Streptococcus*, whereas samples without MPs were dominated by *Enterobacter*, *Escherichia*, and *Pseudomonas*, suggesting a possible association between MPs and alterations in milk microbiota.

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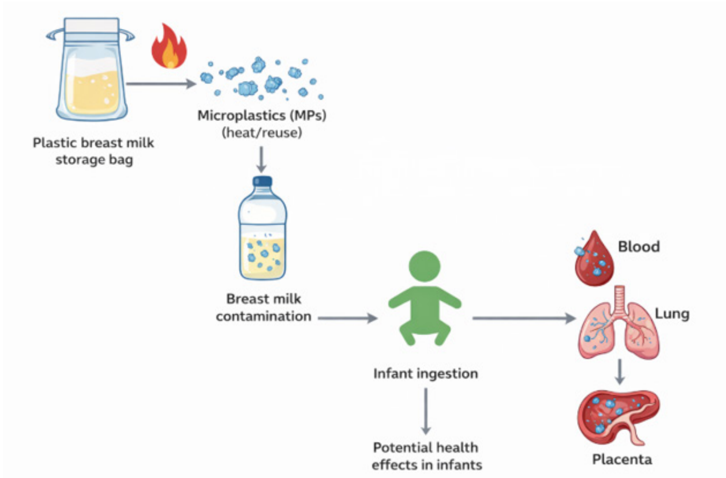

Figure 1. Mechanism of MPs release from breast milk storage bags and their potential exposure pathways in infants (created by the authors based on L. Liu et al., 2023)

MPs in Infant Feces

The presence of MPs in breastmilk is further supported by evidence of infant exposure. The finding of MPs in infant feces confirms the presence of MPs exposure that passes through the gastrointestinal tract, with an abundance of total MPs reaching 26.6 particles per g, consisting of polylactic acid (PLA) 11.1 particles/g, polyurethane (PU) 10.1 particles/g, polyamide (PA) 9.7 particles/g, polystyrene (PS) 8.9 particles/g, and ethylene vinyl acetate copolymer (EVA) 5.6 particles/g. In addition to breastmilk, other reported exposure sources included plastic baby bottles, toys, ambient air, and drinking water (S. Liu et al., 2023), indicating that infant exposure is cumulative and multifactorial.

Environmental Contamination

Beyond direct feeding-related sources, environmental contamination represents an additional pathway of exposure. The increasing use of plastic materials has led to widespread contamination of air, water, and soil by MPs. Reported concentrations include 1,586–11,130 fibers/m^2/day in air, approximately 1200 (±133.2) particles/m^3 in ocean water, and up to 4.1 × 10^5 particles/kg in soil. Such contamination contributes to ecological disruption, including impaired growth and reproduction of small organisms such as zooplankton. Moreover, MPs can act as substrates for pathogenic microorganisms, potentially altering microbiota composition and increasing health risks. These environmental reservoirs may indirectly contribute to maternal exposure and subsequent transfer to infants through the food chain (Mammo et al., 2020).

DISCUSSION

This narrative review highlights growing evidence that MPs are detectable in breastmilk, infant feces, and infant-related feeding products. Experimental findings consistently demonstrate that plastic breastmilk storage bags can release MPs, particularly under conditions of heat exposure, prolonged storage, or improper use. However, it remains uncertain to what extent this exposure translates into clinically meaningful health outcomes in infants.

What is known vs unknown

Current evidence consistently confirms the presence of MPs in breastmilk and infant biological samples, indicating that early-life exposure is occurring. Several experimental and

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observational studies also support the ability of MPs, particularly small-sized particles, to cross the gastrointestinal barrier. However, important uncertainties remain. Most available data are derived from in vitro and animal models, with limited direct evidence in human infants. In addition, variability across studies in terms of detection methods, particle size classification, and reported concentration limits comparability. While some studies report relatively higher concentrations of MPs in breastmilk, others primarily emphasize detection frequency, highlighting inconsistencies in current measurement approaches and the need for standardized methodologies.

Polymer Composition and Environmental Presence

The increasing use of plastic waste in everyday life has increased the presence of MPs. The presence of MPs in the environment causes serious pollution problems worldwide. Types of MPs can be PLA, PU, PA, PS, EVA, as well as other plastics such as polyvinyl chloride (PVC), polypropylene (PP), and polyethylene (PE) (S. Liu et al., 2023; Saraluck et al., 2024). Among these, PE and PP are particularly relevant to infant exposure, as they are widely used in food packaging, bottles, and plastic storage bags, including breastmilk storage products. PP is often selected for its heat-resistant properties, whereas PVC is commonly used in construction-related materials and contributes primarily to environmental background exposure (Saraluck et al., 2024).

Once released into the environment, MPs persist for prolonged periods and accumulate in multiple environmental compartments, including water, soil, and air. Environmental studies have consistently demonstrated that MPs are ubiquitous in freshwater systems, marine environments, and even atmospheric samples, enabling continuous human exposure through ingestion and inhalation (Fackelmann & Sommer, 2019; Chia et al., 2025). This widespread distribution creates a feedback loop in which plastic waste derived from infant-care products may ultimately re-enter the human body through contaminated food, drinking water, and air.

MPs in the environment also act as vectors for chemical pollutants and microorganisms. Polymers such as polystyrene (PS) and polyethylene possess hydrophobic surfaces that facilitate the adsorption of heavy metals, hydrocarbons, and persistent organic pollutants. These contaminated particles may enhance the environmental mobility and bioavailability of toxic substances, increasing their potential to enter the food chain (Mammo et al., 2020; Yan et al., 2023). In addition, MPs can serve as substrates for microbial colonization, forming so-called “plastispheres” that may alter microbial ecosystems in aquatic and terrestrial environments (Luo et al., 2023).

The environmental burden of MPs is particularly concerning in the context of maternal and infant health. Pregnant and lactating women may be exposed to environmental MPs through diet, drinking water, and air, potentially contributing to maternal body burden and subsequent transfer to breastmilk. Although direct causal pathways remain insufficiently elucidated, the detection of MPs in human breastmilk suggests that environmental contamination may indirectly influence infant exposure even before storage-related factors are considered (Saraluck et al., 2024).

Taken together, these findings indicate that PS may exhibit greater biological reactivity compared to other commonly detected polymers such as polyethylene and polypropylene, which are generally considered more chemically inert. The higher surface reactivity of PS, particularly at nano-scale sizes, along with its ability to

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generate reactive oxygen species and adsorb environmental contaminants, may contribute to its increased toxic potential. This suggests that polymer type plays an important role in determining the biological impact of MPs, and that not all MPs pose equal risks, especially in vulnerable populations such as infants.

Biological Interactions and Microbiota Considerations

Among the identified polymers, polystyrene has received increased attention due to its biological interactions. Experimental studies have shown that PS particles can inhibit the growth of Gram-negative bacteria such as *Escherichia coli*, while exerting less inhibitory effect on Gram-positive bacteria, including *Bacillus cereus*. This differential susceptibility is attributed to variations in bacterial cell wall structure: Gram-negative bacteria possess a thinner peptidoglycan layer that may facilitate interactions with PS particles, whereas Gram-positive bacteria are protected by a thicker peptidoglycan layer. In addition, environmental factors such as salt concentration and organic matter content may influence PS particle behavior and bioavailability. These interactions suggest that MPs have the potential to disrupt microbial balance in body fluids, including breastmilk, with implications for infant health, as observed in human observational studies (Saraluck et al., 2024).

Breastmilk Storage Practices as a Modifiable Exposure Source

Plastic breastmilk storage bags are commonly marketed as single-use disposable products. According to the United States Centers for Disease Control and Prevention, breastmilk stored in plastic bags may be kept for up to four hours at room temperature (25°C) or up to four days under refrigerated conditions (4°C) (Ziani et al., 2023). In practical settings, refrigerated breastmilk is frequently warmed while still in the plastic bag before feeding. Experimental evidence indicates that heat exposure under these conditions may increase MP release into breastmilk, suggesting that storage and warming practices represent a modifiable source of infant exposure (Mišľanová et al., 2024).

Exposure Routes and Absorption

MPs are not limited to breastmilk but are also detected in plastic toys, drinking water, and ambient air, resulting in cumulative exposure from infancy through adolescence (Chia et al., 2025). MPs enter the human body through various routes, such as absorption through the skin, inhalation, and ingestion, which have been widely reported, considering their widespread presence in the environment (Fackelmann & Sommer, 2019). Following ingestion, MPs measuring less than 2.5 µm may translocate across the gastrointestinal barrier through endocytosis mediated by M cells in Peyer's patches. This process facilitates the transfer of MPs from the intestinal lumen into mucosal lymphoid tissue. In addition, MPs may penetrate the intestinal epithelium via paracellular permeation through epithelial junctions in the desquamation zone at the tips of intestinal villi. Due to their hydrophobic chemical properties and capacity to interact with biological membranes, MPs may activate inflammatory pathways and induce cellular stress responses, providing biological plausibility for systemic toxicity following oral exposure (Campanale et al., 2020).

Evidence from Experimental Models and Research Gaps

Evidence regarding MP toxicity is predominantly derived from animal and in vivo experimental studies. Reported effects include disruption of energy metabolism, lipid

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dysregulation, oxidative stress, genotoxicity, neurotoxicity, and alterations in the composition of the gut microbiota. Polystyrene MPs, in particular, have been associated with impaired liver function and lipid metabolism in rodent models, as indicated by increased reactive oxygen species and hepatic lipid accumulation. Additional studies have reported adverse effects on reproductive, pulmonary, hepatic, and renal systems following MP exposure (Mammo et al., 2020; Osman et al., 2023; Ziani et al., 2023).

Particle size appears to influence toxicity, as nano-sized PS particles accumulate more readily in tissues, particularly within the gastrointestinal tract, and induce more severe biological effects than larger particles. Oxidative stress has been identified as a central mechanism leading to DNA damage and increased expression of tumor-related proteins, raising concerns regarding the potential carcinogenic properties of chronic PS exposure (Ding et al., 2024). Among the various polymer types, polystyrene appears to exhibit the most pronounced toxicological effects in experimental models, particularly at nano-scale particle sizes (Sultan et al., 2024). Nevertheless, current evidence regarding MP toxicity in humans, especially in infants, remains indirect and largely extrapolated from animal and in vitro studies (Sun & Wang, 2023).

Experimental studies have also reported adverse effects on multiple organ systems. In the reproductive system, MP exposure through drinking water has been associated with accelerated ovarian tumor growth, reduced sperm quality, and impaired embryo production (Chen et al., 2024; Deng et al., 2022; Wei et al., 2022). In the respiratory system, PS exposure has been shown to induce oxidative stress, inflammation, and alterations in cell cycle–related protein expression in human epithelial cells (Xu et al., 2019; Yang et al., 2021). Hepatic and renal inflammation and tissue injury have been observed in murine models following PS exposure (Zhao et al., 2021; Zheng et al., 2021). Additionally, PS has been shown to enhance the cytotoxicity of environmental toxins in human fecal samples (Yan et al., 2023).

Infants represent a particularly vulnerable population due to several biological factors, including gastrointestinal immaturity, higher intestinal permeability, developing immune systems, and relatively higher intake of milk per body weight (Fournier et al., 2023; Mišľanová et al., 2024; Park et al., 2025). These factors may increase the likelihood of MP absorption and systemic distribution during a critical developmental window (Esposito et al., 2025).

From a clinical perspective, pediatricians and lactation specialists should be aware of potential MP exposure associated with breastmilk storage practices (Zhao et al., 2025). While breastfeeding remains unequivocally the optimal source of infant nutrition, simple precautionary measures may help reduce unnecessary exposure (Sincihu et al., 2025). These include avoiding warming breastmilk inside plastic storage bags, preferring sterile glass containers for storage when feasible, using plastic storage bags strictly as single-use products, and avoiding high-temperature sterilization of plastic materials (Zhao et al., 2025).

Despite growing concern, significant knowledge gaps remain (Hoang et al., 2025). To date, no studies have directly correlated MP concentrations in breastmilk with specific clinical outcomes in infants (Chartres et al., 2024). Longitudinal human studies examining dose–response relationships, developmental outcomes, and potential cumulative effects are urgently needed. In parallel, regulatory frameworks should consider establishing safety standards and MP limits for breastfeeding-related products to better protect infant health (Ali et al., 2025).

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CONCLUSION

Plastic-based breast milk storage bags may represent a potential source of microplastic exposure for infants and contribute to broader environmental contamination. Available evidence indicates that MPs can be released from these products, particularly under conditions of heat exposure, prolonged storage, or improper use, and may subsequently be ingested by infants during a critical period of development. Although current data suggest possible biological interactions and health implications, direct evidence linking microplastic exposure from breast milk to specific clinical outcomes in infants remains limited. Therefore, increased awareness of safer breast milk storage practices, alongside further well-designed human studies and regulatory consideration of microplastic safety in infant-feeding products, is essential to minimize exposure and support infant and environmental health.

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