Occurrence of Microplastics in Selected Liquid Oral Medications and Intravenous Infusions in Sri Lanka

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Abstract
Microplastics (MPs) are increasingly recognized as emerging contaminants in clinical environments, suggesting novel exposure routes beyond dietary and inhalation routes. This study provides the first systematic investigation of MP contamination of selected intravenous (IV) fluids and oral liquid medications in Sri Lanka. Eleven medicinal liquids (four IV fluids and seven oral preparations) were collected from government and private healthcare facilities based on their frequency of usage and analyzed under strict quality control conditions in a laminar hood facility. Microplastics were extracted by vacuum filtration through 0.45 µm cellulose nitrate filters and identified by stereomicroscopy and hot needle testing. All samples contained MPs, with normal saline IV fluids showing a mean concentration of 15.30 ± 3.28 MPs per 100 mL and oral liquids 69.98 ± 43.35 MPs per 100 mL. Fragments and fibres were the dominant morphologies, consistent with global reports linking MPs to packaging and handling. These findings highlight a critical gap in pharmaceutical quality control, particularly considering the direct systemic exposure risk posed by IV infusions. Establishing monitoring systems, enhancing packaging standards, and formulating regulatory frameworks are urgently needed to mitigate MP associated in healthcare products as emerging contaminants, posing direct threats on human.

I. Introduction

Microplastics (MPs), defined as plastic particles less than 5 mm in size, have emerged as ubiquitous contaminants in the environment, permeating air, water, soil, and even the human food chain through sources like fish and shellfish [1],[2]. Originally recognized as an ecological hazard in marine environments, microplastics have now been detected in remote ecosystems, potable water, and atmospheric fallout [3],[4]. Their resilience against degradation, combined with their widespread dispersion, underscores the complexity of their management as a pollutant [5].

Historically, research on human exposure to MPs focused on dietary and inhalation pathways, with ingestion via seafood, drinking water, and table salt being prominent [6],[7]. However, emerging evidence suggests alternative, non-dietary exposure routes, including intravenous (IV) infusion and inhalation during clinical care [8],[9]. This challenges the traditional understanding of exposure pathways and raises significant toxicological and clinical safety concerns [10].

Recent biomedical studies have revealed MPs in human lung tissue [11], liver [12], blood [13], and even reproductive organs [14]. Bioaccumulation potential is now evident, with MPs being detected in postmortem brain tissue [15] and in patients undergoing invasive medical procedures [9]. These findings provide strong evidence that MPs can translocate across physiological barriers, potentially inducing systemic health effects [16].

While environmental sources remain significant, MPs have now been detected in clinical settings, particularly within pharmaceutical liquids and IV solutions [17],[18]. The discovery that infusion therapy may act as a direct pathway for MPs into the bloodstream represents a paradigm shift in medical safety research [19]. Given that IV fluids bypass gastrointestinal filtration, MPs introduced through this route may pose greater systemic risks than dietary exposures [8].

Pharmaceutical contamination may arise from polymer-based manufacturing processes, packaging materials, and clinical handling systems [20],[21]. Polyethylene terephthalate (PET), polypropylene (PP), and polyvinylpyrrolidone (PVP) are commonly used in medical packaging and formulation, each with varying degradation profiles and toxicological risks [21],[22].

During preparation, transportation, and administration, MPs can be shed from plastic containers, infusion sets, and syringe barrels [23],[24].

The toxic effects of MPs depend on polymer type, particle size, surface chemistry, and associated chemical additives [25]. Studies have shown that polystyrene nano plastics can induce pro-inflammatory immune responses, disrupt cellular function, and potentially cause genotoxic effects [25]. Furthermore, MPs can act as carriers for environmental contaminants, enhancing their bioavailability and compounding toxicity [26].

The presence of MPs in intravenous (IV) fluids, such as saline and dextrose, has been documented in international studies [17],[18], as well as in milk-based pharmaceuticals and oral liquid medications [27]. Detection techniques range from Fourier-transform infrared spectroscopy (FTIR) to pyrolysis-gas chromatography–mass spectrometry (Pyr-GC/MS), each with strengths and limitations for polymer identification [28],[29].

In Sri Lanka, intravenous (IV) therapy is a fundamental and high-volume procedure in both public and private healthcare sectors, with large quantities of normal saline and other solutions administered daily. Despite of this immense usage pharmaceutical liquids including both IV and oral solutions, no extensive studies have been conducted on potential MP contamination through these procedures, creating a critical gap in the scientific literature. This oversight creates a significant blind spot in patient safety monitoring and pharmaceutical quality control. The risk is heightened by the healthcare system's reliance on a supply chain that includes both local and international manufacturers, where medical liquids are packaged in common plastic materials known to shed MPs under mechanical and thermal stresses. Given the widespread use of these products in vulnerable populations like neonatal, oncology, and critical care patients, even low-level MP contamination could pose amplified health risks, such as enhanced inflammation or organ-specific toxicity, in the absence of a regulatory framework.

To address this significant gap, this study aims to be the first to detect, quantify, and characterize microplastics in pharmaceutical liquids administered in Sri Lankan healthcare facilities. Our research will focus on locally prevalent normal saline IV fluids and oral liquid medications. We will quantify the microplastic load and characterize the morphological types, such as fibers and fragments, and explore potential sources of contamination for each product category. The findings will provide essential baseline data for comprehensive risk assessment and will serve as a crucial foundation for informing local policymakers and healthcare providers. By filling this critical research gap, this study will contribute to the global understanding of MPs as emerging contaminants in the medical field and will locally inform quality control measures, potentially guiding the development of new procurement policies and regulatory standards for pharmaceutical products in Sri Lanka.

II. MATERIALS AND METHODS

A. Sample acquisition and characterization

A total of 11 distinct medicinal liquid varieties, packaged in single-use plastic containers, were collected for analysis. All samples were acquired from pharmacies and healthcare facilities located within the Colombo metropolitan area of Sri Lanka. This sample set included 4 varieties of intravenous (IV) fluids and 7 varieties of oral medicinal liquids, representing products commonly used in both government and private healthcare facilities. The selection was designed to be representative of the market, incorporating both locally manufactured and imported products, as well as products from various manufacturing timeframes to account for potential batch-to-batch variations. The samples covered a broad range of patient demographics, from pediatric to adult applications.

TABLE I SAMPLE DESCRIPTION

Sample code	Sample details	Manufactured country	Post – manufacture period
S-1	Normal saline / NaCl 0.9% (500ml)	Sri Lanka	12 months
S-2	Normal saline / NaCl 0.9% (500ml)	China	12 months
S-3	Normal saline / NaCl 0.9% (500ml)	India	12 months
S-4	Normal saline / NaCl 0.9% (500ml)	China	12 months
S-5	Indigenous Medicinal Syrup (350ml)	Sri Lanka	12months
S-6	Vit-B Complex Syrup (250ml)	India	6months
S-7	Infant Carminati	Sri Lanka	6months

	ve Syrup (100ml)		
S-8	Cetirizine Syrup (60ml)	India	24months
S-9	Chlorpheniramine maleate syrup (100ml)	Sri Lanka	36months
S-10	Terbutaline syrup (100ml)	India	24months
S-11	Cough syrup (100ml)	India	6months

B. *Microplastic extraction*

The microplastic (MP) extraction protocol was adapted from the method described in Nandikes et al. [30], *Separation, Identification, and Quantification of Microplastics in Environmental Samples.* Due to the low organic content of the IV fluids and oral medicinal liquids, procedures for density separation and organic matter digestion were omitted. This streamlined the extraction process, focusing directly on filtration.

To prepare the samples for filtration, any medicinal liquid with high viscosity was diluted with RO water in a ratio of 2:1 or 1:1. All filtration steps were performed in a laminar flow cabinet to minimize potential environmental MP contamination. The samples were filtered through a vacuum filtration setup using a suction pump. A 0.45 µm pore-sized gridded cellulose nitrate filter paper (SARTORIUS stedim biotech GmbH) was used to capture the particles.

After filtration, the filter papers were carefully transferred to sterile glass Petri dishes and placed in a Gallenkamp hot box oven. They were dried at a temperature of 30–40 °C for 15–30 minutes to remove all residual moisture.

C. *Microplastic Identification*

Microplastic (MP) particles were identified and characterized using a two-step process. Initial screening and quantification were performed using a stereo microscope to count particles and observe their morphological features and color. This step allowed for the preliminary distinction of potential MPs from other non-plastic contaminants. The count was categorized by particle shape, predominantly fibres and fragments.

Following microscopic analysis, the identification of suspected MPs was confirmed using the hot needle test. This is a simple, destructive method where a heated needle is used to probe a particle; a plastic particle will deform, melt, or curl, while non-plastic particles (like dust or glass) will not. This method, as described in studies by Beckingham et al.,[31], provides a rapid, on-site confirmation of the plastic nature of the particles.

D. *Quality Assurance and Quality Control*

To ensure the accuracy and reliability of the microplastic analysis, a strict Quality assurance and quality control (QA/QC) protocol was implemented to minimize potential contamination. All equipment was meticulously cleaned with a triple-rinse of reverse osmosis (RO) water followed by acetone, a non-polar solvent chosen for its efficiency in removing residues and facilitating water removal. After cleaning, equipment was stored in a closed cabinet to prevent ambient contamination. All solutions were pre-filtered through 0.45 µm cellulose nitrate filters to eliminate any existing microplastic particles before use.

All analytical procedures were conducted within a closed laminar flow cabinet to reduce airborne contamination. Samples were protected with aluminum foil during storage. As a standard protocol, all work surfaces were wiped with acetone before and after each session. Microscopic analyses were performed inside a closed cabinet to further minimize exposure. To prevent fibre shedding from synthetic clothing, laboratory personnel wore cotton laboratory coats.

To control for laboratory contamination, blank filter papers were exposed under identical conditions to the experimental samples. The absence of microplastic particles on these blanks confirmed that the laboratory environment did not introduce contamination, validating the integrity of the results.

III. RESULTS AND DISCUSSION

Microplastics (MPs) were detected in all 11 pharmaceutical liquid products analyzed, encompassing both intravenous (IV) fluids and oral medicinal syrups. Particle counts varied considerably across samples, with distinct differences observed between product categories.

All four normal saline IV samples (S1–S4) contained detectable MPs with a mean abundance across IV fluids of 76.50 ± 16.39 MPs per sample (15.30 ± 3.28 MPs per 100 mL). The highest concentration was recorded in sample S1, with 97.67 MPs per sample (19.53 MPs/100 mL), while the lowest was observed in S2, with 57.67 MPs per sample (11.53 MPs/100 mL). Morphological analysis revealed that fragments significantly dominated, with an average of 77.99 ± 6.98% of total particles, whereas fibers accounted for 22.00 ± 6.98% ($t = 8.02$, $p = 0.004$). These results suggest that packaging-related shedding, likely from polypropylene containers, is a primary source of contamination in IV fluids.

Compared to other medications, oral medicinal liquids exhibited significantly higher microplastic concentrations (t test, $t=4.3$, $p = 0.016$ compared to oral medications, Figure 1.0). Across the seven products (S5–S11), the mean abundance was 73.24 ± 18.32 MPs per sample (69.98 ± 43.35 MPs per 100 mL). Among these, Cetirizine syrup (S8) showed the highest contamination level at 138.06 MPs/100 mL, while the lowest was recorded in Cough syrup (S11) at 46.67

MPs/100 mL. On average, fragments accounted for 85.68 ± 5.26% of particles, while fibers made up 14.31 ± 5.26% resulting significant contribution from fibers ($t = 17.94$, $p < 0.000001$). These higher levels of fragments in syrups may be attributed to extended storage times, container design, and the physicochemical properties of PET packaging.

When all samples were considered together, the total mean abundance was 74.43 ± 16.87 MPs per sample (50.10 ± 43.48 MPs/ 100 mL). Fragments were the predominant morphology across both product categories, representing more than four-fifths of the total particles identified, while fibers consistently made up a smaller proportion. No other morphotypes (e.g., films or beads) were observed in this study.

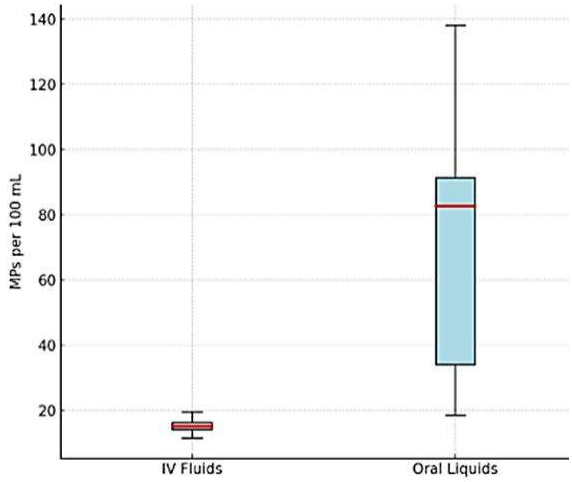

Figure 1: Overall contamination of microplastics in IV fluids and oral liquid medications, revealing significantly higher levels of MPs in oral medications ($p<0.05$)

The differences between IV fluids and oral liquids indicate that, although IV solutions carry a lower particle load, they may pose a higher clinical risk due to their direct systemic administration route. In contrast, oral medications displayed a higher variability in MP concentrations, possibly reflecting manufacturing and storage heterogeneity.

The detection of MPs in all analyzed intravenous and oral medicinal liquids highlights the growing concern that pharmaceutical products themselves may serve as direct vectors of microplastic exposure. The dominance of fibres and fragments in both categories aligns with previous research attributing MP contamination to polymer shedding from packaging and handling systems [24],Polypropylene and polyethylene terephthalate, widely used in containers and infusion sets, are well-documented sources of leachable MPs [21].

The comparatively higher MP load in oral liquids (69.98 ± 43.35 MPs/100 mL) relative to IV solutions (15.30 ± 3.28 MPs/100 mL) suggests that extended storage periods, higher viscosity, and bottle reusability may increase the risk of contamination, consistent with similar findings in milk-based pharmaceuticals and syrups [27]. However, the lower concentrations in IV fluids should not be overlooked; despite the reduced counts, IV administration represents a more critical exposure pathway, bypassing gastrointestinal filtration and allowing MPs direct access to systemic circulation

Toxicological evidence indicates that MPs can translocate across epithelial and endothelial barriers, reaching organs such as the liver, lungs, reproductive tissues, and even the brain [13],[14],[15]. Given the use of IV fluids in vulnerable populations—such as neonates, oncology patients, and those in intensive care—the risks of even trace MPs are amplified. Pro-inflammatory responses, oxidative stress, and potential genotoxicity of nano plastics further exacerbate this concern[25],[26].

The findings highlight a crucial regional data gap in MP contamination in medical drugs as the most published studies originate from Europe and East Asia [17]. The identification of MPs in pharmaceutical liquids within a South Asian context underscores that this is a global issue, independent of geographic or economic boundaries. The findings therefore strengthen the call for international collaboration in developing standardized monitoring protocols, building on established contamination control frameworks already emphasized in environmental MP research [32].

TABLE II RESULTS SUMMARY

Sample Type	Sample Code	Fragments		Fiber		MPs per sample	MPs per 100ml
		Count	Percentage	Count	Percentage		
Intravenous infusions	S1	68	69.62	29.67	30.37	97.67	19.53
	S2	49.67	86.13	8.00	13.87	57.67	11.53
	S3	60.00	80.35	14.67	19.64	74.67	14.93
	S4	57.67	75.88	18.33	24.12	76.00	15.20
	Mean	58.84±7.54	77.99±6.98	17.67±9.07	22.00±6.98	76.50±16.39	15.30±3.28
Liquid oral medications	S5	49.33	76.29	15.33	23.71	64.66	18.47
	S6	48.33	90.62	5.00	9.38	53.33	21.33
	S7	73.33	81.78	16.33	18.21	89.66	89.66
	S8	73.00	88.3	9.67	11.7	82.67	138.06
	S9	84.33	90.67	8.67	9.32	93.00	93.00
	S10	69.67	84.27	13.00	15.73	82.67	82.67
	S11	41.00	87.85	5.67	12.15	46.67	46.67
	Mean	62.71±16.29	85.68±5.26	10.52±4.49	14.31±5.26	73.24±18.32	69.98±43.35
	Total Mean	61.30±13.42	82.88±6.80	13.12±7.06	17.11±6.80	74.43±16.87	50.10±43.48

IV. Conclusion

This study provides the first evidence of microplastic contamination in commonly prescribed oral liquid medicines and intravenous fluids in Sri Lanka, confirming that MPs are present across all examined products. While oral medications contained higher concentrations, intravenous infusions present greater systemic risk due to the direct entry of MPs into the bloodstream. The dominance of fibres and fragments suggests that packaging and handling are key contamination sources. These findings highlight an overlooked dimension of pharmaceutical safety, with implications for patient health, particularly in vulnerable groups.

To address the emerging risks posed by microplastics in pharmaceutical products, several key measures are warranted. First, clear regulatory standards must be established at both national and international levels to ensure pharmaceutical quality control. Manufacturers should be encouraged to adopt low-shedding or biodegradable packaging innovations that minimize microplastic release. Furthermore, routine monitoring of intravenous and oral medicinal liquids for MPs should be integrated into existing quality assurance protocols. Equally important is raising clinical awareness by training healthcare professionals to reduce handling-related contamination during preparation and administration. Further

research, particularly polymer-specific identification using advanced techniques such as FTIR and Raman spectroscopy, is essential to better understand contamination sources and toxicological risks. Finally, policy integration is critical, with MP monitoring incorporated into broader environmental and public health frameworks in Sri Lanka, thereby safeguarding patient safety and aligning with global best practices.

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