Research Square

Preprints are preliminary reports that have not undergone peer review.
They should not be considered conclusive, used to inform clinical practice,
or referenced by the media as validated information.

From bathroom to wastewater: a systematic review of microplastic sources, polymer characteristics, and treatment challenges

Ahmad Jahedi
Faculty of Civil Engineering, Islamic Azad University, Dezful Branch, Dezful, Iran
Faezeh Jahedi
fjahedi1369@gmail.com
Ahvaz Jundishapur University of Medical Sciences: Ahvaz Jondishapour University of Medical Sciences https://orcid.org/0000-0002-2744-5101
Afshin Takdastan
Ahvaz Jundishapur University of Medical Sciences
Neamatollah Jaafarzadeh Haghighi Fard
Ahvaz Jundishapur University of Medical Sciences

Systematic Review

Keywords: Microplastics, Bathroom products, Wastewater treatment, Personal care products, Systematic review, Polyethylene, Emission pathways, Urban water

Posted Date: October 28th, 2026

DOI: https://doi.org/10.21203/rs.3.rs-11467627/v1

License: This work is licensed under a Creative Commons Attribution 4.0 International License. Read Full License

Additional Declarations: The authors declare no competing interests.

Abstract

Background

Microplastics (MPs) are increasingly recognized as emerging contaminants in urban water systems. While many sources have been studied, the bathroom – as a point of discharge for personal care products, synthetic textiles, and plastic packaging – remains an under-quantified contributor to MP pollution in domestic wastewater.

Objective

This systematic review synthesizes peer-reviewed evidence on the composition, release pathways, and removal efficiency of bathroom-derived MPs in urban wastewater, and identifies critical knowledge gaps.

Methods

A systematic search was performed in PubMed, Scopus, and Web of Science for articles published between 2010 and 2024, following PRISMA 2020 guidelines. After screening, 26 studies met the inclusion criteria. Data were extracted on polymer type, particle size, concentration, emission pathways, and wastewater treatment removal rates. Quality was assessed using the Mixed Methods Appraisal Tool (MMAT).

Results

Polyethylene (PE) and polypropylene (PP) were the dominant polymers, detected in 73% of studies. Particle sizes ranged from 50 to 500 μm, with concentrations varying from 10^2 to 10^6 particles per gram of product. Wastewater discharge was the principal emission pathway. Conventional wastewater treatment plants (WWTPs) removed less than 70% of particles smaller than 100 μm. Synthetic bathroom textiles and plastic packaging were consistently identified as additional, often overlooked sources. No study quantified MP release from plastic fixtures (e.g., showerheads, PVC pipes) under real-use conditions.

Conclusion

Bathroom-derived MPs are a significant but largely neglected contributor to MP pollution in urban wastewater. The consistently low removal of particles < 100 μm by conventional WWTPs indicates that a large fraction is discharged into receiving waters. Closing the identified knowledge gaps – particularly regarding textile microfibers, packaging degradation, and fixture emissions – requires standardized detection methods, field-based emission studies, and investment in tertiary treatment. Without these actions, bathroom-derived MPs will continue to undermine water quality and aquatic ecosystem health.

1. Introduction

Microplastics (MPs), plastic particles smaller than 5 mm, have become ubiquitous environmental contaminants detected in water, soil, air, and biota [1–4]. While extensive research has focused on high-volume sources such as marine litter, industrial effluents, and laundry discharge, domestic sources—particularly the bathroom—have received far less attention, despite their potential to contribute significantly to MP emissions[5, 6].

The bathroom serves as a source of diverse plastic-containing products, including personal care products (PCPs), synthetic fabrics (e.g., towels and bathrobes), plastic packaging, and accessories such as toothbrushes and razors. Among these, rinse-off cosmetics and personal care products (C&PCPs) have been identified as a primary source of primary MPs, as microbeads—predominantly polyethylene (PE) and polypropylene (PP)—are intentionally incorporated as exfoliants, thickeners, or structuring agents [7].

The presence of plastic microbeads in cosmetics was first reported in 1991 by Zitko and Hanlon [8], who found that up to 46% (by weight) of certain face scrubs consisted of polystyrene (PS) microplastics. However, public and scientific interest only began to grow in the early 2010s following landmark studies such as Fendall and Sewell [9], who provided the first quantitative estimates of

MPs in facial cleansers. Subsequent research from New Zealand [10] confirmed the widespread but variable occurrence of MPs in commercial products, with PE microplastics detected in hand cleaners and facial scrubs—sometimes constituting up to 6% of product weight. A pioneering study by Napper et al. [11]not only quantified MP concentrations in six face washes (up to 19,000 particles per mL) but also demonstrated their capacity to adsorb and transport environmental pollutants such as phenanthrene and DDT, highlighting the dual threat of MPs: physical contamination and chemical vectoring.

Beyond personal care products, synthetic bathroom textiles (e.g., towels, bath mats, robes) shed microfibers during routine use and laundering. Conventional wastewater treatment plants (WWTPs) fail to efficiently capture particles below 100 μm, resulting in significant MP release into natural watercourses [12, 13]. MPs have subsequently been detected in seafood, tap water, salt, and even human tissues, raising concerns over health effects including inflammation, oxidative stress, and endocrine disruption [14].

Despite mounting evidence, no systematic review has comprehensively synthesized MP sources, emission pathways, and management challenges specific to bathroom-related products. Previous reviews have focused either on cosmetics alone[15, 16] or on laundry microfibers [17], without integrating other bathroom sources such as plastic packaging, accessories, and fixtures. Furthermore, the role of conventional WWTPs as a pathway from bathroom to aquatic ecosystems remains underexplored.

To address these gaps, this systematic review, conducted in accordance with PRISMA 2020 guidelines, synthesizes peer-reviewed literature published between 2010 and 2025 to characterize the types, concentrations, and physicochemical properties of microplastics in bathroom-related products, identify their main release pathways into wastewater, evaluate the removal efficiency of conventional and advanced treatment processes, and assess the management challenges and mitigation strategies currently proposed. By integrating these dimensions, this review provides a holistic evidence base for policymakers, manufacturers, and water managers aiming to reduce microplastic pollution from domestic sources.

2. Materials and Methods

2.1. Study Design

This systematic review was conducted following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 guidelines. The review protocol was not registered in a public database. The study aimed to synthesize peer-reviewed literature on microplastic (MP) contamination from bathroom-related products, including their physicochemical characteristics, emission pathways, and implications for wastewater management.

2.2. Information Sources

A comprehensive search was performed across three electronic databases: PubMed, Scopus, and Web of Science. These databases were selected for their broad coverage of biomedical, environmental, and engineering sciences.

2.3. Search Strategy

Boolean search strings were customized for each database to retrieve studies published between January 1, 2010, and December 31, 2025. The full search strategies are provided below:

PubMed:

(("microplastics"[Title/Abstract] OR "microbeads"[Title/Abstract])AND ("toothpaste"[Title/Abstract] OR "shampoo"[Title/Abstract]OR "scrub"[Title/Abstract] OR "exfoliator"[Title/Abstract]

OR "face wash"[Title/Abstract] OR "bathroom"[Title/Abstract])AND ("pollution"[Title/Abstract] OR "emission"[Title/Abstract] OR "wastewater"[Title/Abstract]))AND ("2010/01/01"[Date - Publication] : "2025/12/31"[Date - Publication])AND (english[Language])

Scopus:

TITLE-ABS("microplastics" OR "microbeads")AND TITLE-ABS("toothpaste" OR "scrub" OR "shampoo" OR "exfoliator" OR "face wash")AND TITLE-ABS("pollution" OR "release" OR "wastewater" OR "environmental impact")AND PUBYEAR > 2009 AND PUBYEAR < 2025

AND (LIMIT-TO(DOCTYPE, "ar"))AND (LIMIT-TO(LANGUAGE, "English"))

Web of Science:

TS=("microplastics" OR "microbeads")AND TS=("toothpaste" OR "shampoo" OR "face wash" OR "scrub" OR "exfoliator") AND TS=("pollution" OR "release" OR "wastewater")

AND PY=(2010–2025)AND LA=(English)AND DOCUMENT TYPES: (Article)

2.4. Eligibility Criteria

Studies were included if they were published between 2010 and 2025, were original peer-reviewed research articles (reviews, editorials, commentaries, conference abstracts, and letters were excluded), focused on the detection, quantification, or characterization of microplastics in bathroom-related products including personal care products, synthetic textiles, plastic packaging, and accessories, reported at least one of the following parameters: particle size, polymer type, concentration, or emission pathway, and were written in English. Studies were excluded if they did not specifically address bathroom-related products, such as general environmental microplastic surveys without product-level data, lacked quantifiable microplastic data and only reported qualitative presence or absence, or were not peer-reviewed.

2.5. Study Selection

A total of 126 records were retrieved from the three databases: 21 from PubMed, 57 from Scopus, and 48 from Web of Science. After importing into Zotero and removing 41 duplicates, 85 unique records remained for title and abstract screening. During the title and abstract screening phase, 49 records were excluded for the following reasons: 21 records were irrelevant to bathroom-related products, 14 records focused on general environmental microplastic pollution without product specificity, 9 records were review articles, editorials, or short communications, and 5 records were not in English. The remaining 36 full-text articles were assessed for eligibility. After detailed evaluation, ten articles were excluded: six lacked quantitative data or product specificity, and four had poor methodological clarity, such as undefined extraction procedures. Ultimately, 26 studies were included in the final systematic review. The selection process is illustrated in the PRISMA 2020 flow diagram (Fig. 1).

2.6. Data Extraction

A standardized data extraction form was developed using Microsoft Excel. For each included study, the following information was extracted: first author and year of publication, country where the study was conducted, product type (e.g., toothpaste, facial scrub, body wash, shampoo, textile), sample size (number of products tested), polymer type (e.g., PE, PP, PET, PA), particle size (mean, range, or distribution), microplastic concentration (reported as particles per gram, particles per milliliter, or percentage by weight), detection and characterization method (e.g., FTIR, Raman, SEM-EDS), reported emission pathways (e.g., wastewater, landfill, air), and wastewater treatment removal efficiency if reported.

2.7. Quality Assessment and Risk of Bias

Due to substantial methodological heterogeneity among included studies (e.g., different extraction protocols, units of measurement, and product types), a meta-analysis was not feasible.

Quality assessment was performed using the Mixed Methods Appraisal Tool (MMAT) version 2018 [32], which is suitable for descriptive quantitative studies. Each included study was independently evaluated by two authors (F.J. and A.J.) against five MMAT criteria relevant to its study design. Disagreements were resolved through discussion with a third reviewer (N.J.H.F.).

Each criterion was rated as “Yes,” “No,” or “Can’t tell.” The overall quality score was calculated as the percentage of “Yes” responses. Studies scoring ≥ 80% were classified as high quality, 60–79% as moderate quality, and < 60% as low quality. All 26 included studies scored ≥ 80% and were retained for synthesis. A summary of quality scores is provided in Supplementary Table S1.

In addition to MMAT, the following methodological aspects were assessed for each study: clarity of analytical method (e.g., FTIR with spectral matching), sample representativeness (e.g., number of product batches), completeness of reporting of units (e.g., particles/g vs. particles/mL), and description of quality control measures (e.g., blank corrections).

2.8. Data Synthesis

Given the heterogeneity in study design, measurement units, and product types, a narrative synthesis was conducted. Findings were organized around three main themes: (1) physicochemical characteristics of MPs in bathroom products (polymer type, size, shape, concentration), (2) emission pathways to wastewater and the environment, and (3) removal efficiency in conventional and advanced wastewater treatment processes. Quantitative data (e.g., concentration ranges) were compiled and presented in Table 1.

Table 7
Quality appraisal of included studies using MMAT (version 2018)

1	Study	MMAT design category	Q1	Q2	Q3	Q4	Q5	Score (%)	Quality
	Lei, 2017 [18]	**Descriptive quantitative**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**100**	**High**
2	Praveena, 2018 [19]	Descriptive quantitative	Yes	Yes	Yes	Yes	Yes	100	High
3	Ustabasi, 2019 [20]	Descriptive quantitative	Yes	Yes	Can't tell	Yes	Yes	80	High
4	Mon & Nakata, 2020 [21]	Descriptive quantitative	Yes	Yes	Yes	Yes	No	80	High
5	Habib, 2022 [22]	Descriptive quantitative	Yes	Yes	Yes	Yes	Yes	100	High
6	Madhumitha, 2022 [23]	Descriptive quantitative	Yes	Yes	Yes	Yes	Yes	100	High
7	Nawalage & Bellanthudawa, 2022 [24]	Descriptive quantitative	Yes	Can't tell	Yes	Yes	Yes	80	High
8	Singh & Mishra, 2023 [14]	Descriptive quantitative	Yes	Yes	Can't tell	Yes	Can't tell	60	Moderate
9	Napper & Thompson, 2020 [25]	Non-randomized	Yes	Yes	Yes	Yes	Yes	100	High
10	Napper & Thompson, 2022 [11]	Non-randomized	Yes	Yes	Yes	Yes	Yes	100	High
11	Gamage, 2022 [15]	Descriptive quantitative	Yes	No	Yes	Can't tell	Yes	60	Moderate
12	Cheung & Fok, 2016 [26]	Descriptive quantitative	Yes	Yes	Yes	Yes	Yes	100	High
13	Cheung & Fok, 2017 [27]	Descriptive quantitative	Yes	Yes	Yes	Yes	Yes	100	High
14	Kalčíková, 2017 [28]	Descriptive quantitative	Yes	Yes	Yes	Yes	Yes	100	High
15	Dung, 2024 [29]	Descriptive quantitative	Yes	Yes	Can't tell	Yes	Yes	80	High
16	Chang, 2015 [30]	Descriptive quantitative	Yes	No	Yes	Yes	Can't tell	60	Moderate
17	Carr, 2016 [31]	Non-randomized	Yes	Yes	Yes	Yes	Yes	100	High
19	Hernandez, 2017 [32]	Descriptive quantitative	Yes	Yes	Yes	Yes	Yes	100	High
20	Conkle, 2018 [33]	Descriptive quantitative	Yes	Yes	Can't tell	Yes	Yes	80	High
21	Bashir, 2021 [34]	Descriptive quantitative	Yes	Yes	Can't tell	Yes	Yes	80	High
23	Geng, 2023 [35]	Descriptive quantitative	Yes	Yes	Yes	Yes	Yes	100	High
24	Oveisy, 2022 [36]	Descriptive quantitative	Yes	Yes	Can't tell	Yes	Yes	80	High
25	Ben-David, 2021 [37]	Non-randomized	Yes	Yes	Yes	Yes	Yes	100	High

1	Study	MMAT design category	Q1	Q2	Q3	Q4	Q5	Score (%)	Quality
	Lei, 2017 [18]	**Descriptive quantitative**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**100**	**High**
26	Liu, 2021 [38]	Descriptive quantitative	Yes	Yes	Yes				

3. Results

A total of 26 studies met the inclusion criteria and were synthesized. The results are organized according to the four research questions defined in the introduction: (1) characteristics of MPs in bathroom products, (2) emission pathways, (3) removal in wastewater treatment, and (4) management challenges. A summary of the included studies is provided in Table 1.

3.1. Characteristics of MPs in Personal Care Products

3.1.1. Polymer Types

Across the 26 included studies, polyethylene (PE) was the most frequently detected polymer, reported in 73% of studies that performed chemical verification (n = 19/26). Other identified polymers included polypropylene (PP), polyvinyl chloride (PVC), polyethylene terephthalate (PET), polyamide (PA), cellophane (CP), and acrylate copolymers. Detailed polymer distribution by product type is presented in Table 1.

In toothpaste, polymer composition varied across studies. Praveena et al.[19] reported low-density polyethylene (LDPE) as the dominant polymer (3–123 μm, granular morphology). Madhumitha et al. [23] identified four polymer types in Indian toothpaste: CP, PP, PVC, and PA, constituting 0.2–0.9% of product weight. Conversely, three studies reported no detectable MPs in toothpaste samples: Lei et al. [18] (135 samples, 23 brands, analyzed by FTIR and micro-Raman), Mon & Nakata [[21] (three samples, FTIR-ATR), and Habib et al. [22] (33 samples in UAE, FTIR-EDS).

In facial cleansers and body scrubs, PE was the predominant polymer. Cheung & Fok [26]reported PE microbeads in facial scrubs with concentrations ranging from 4,000 to 45,000 particles/g. Kalčíková et al. [28] reported PE in body scrubs with particle counts of 6.25×10^5 to 1.19×10^6 particles/g.

3.1.2. Particle Size and Shape

Reported particle sizes varied considerably across product categories. In facial cleansers, size ranged from 11 μm to 400 μm (mean: 161–380 μm) [19]. In body scrubs, particles ranged from 12 μm to 500 μm, with larger particles (mean: 71.3 μm) associated with exfoliating function. Toothpaste contained smaller particles, typically 3–200 μm [20]. The smallest reported particles (24 ± 6 nm) were identified in facial scrubs by Hernandez et al., indicating the presence of nanoplastics.[32]

Regarding morphology, irregular (fragmented) particles were dominant across all product categories. Spherical particles (microbeads) were reported only in eight studies, exclusively in rinse-off products [14, 18–22, 25, 39].

3.1.3. Concentration

MP concentrations ranged from 10^2 to 10^6 particles/g, with substantial variation both within and between product categories. Facial cleansers showed the highest average concentration (1.23×10^4 particles/g), followed by body scrubs and toothpaste. The lowest concentrations were reported in shower gels (2.15 particles/g on average). In mass-based units, MP content ranged from 0.08% to 9.4% w/w .[19, 25]

Table 1
Comprehensive summary of microplastics in bathroom-related products included in this systematic review

Product category	Specific product	Polymer type	Size (μm)	Concentration	Detection method	Country	Reference
Personal care – toothpaste	Toothpaste (135 samples, 23 brands)	None detected	—	0	FTIR, micro-Raman	China	[18]
	Toothpaste	LDPE	3–123	43,885 ± 2,186 particles/g (7.24% w/w)	FTIR	Malaysia	[19]
	Toothpaste (20 samples, 4 positive)	PE	4–20	0.4–1% w/w	—	Turkey	[20]
	Toothpaste (3 samples)	None detected	—	0	FTIR-ATR	Myanmar	[21]
	Toothpaste (33 samples)	None detected	—	0	FTIR-EDS	UAE	[40]
	Toothpaste	CP, PP, PVC, PA	3.5 – >400	0.2–0.9% w/w	FTIR, SEM	India	[23]
	Toothpaste	PE (52%), PA (30%), PET (15%), PBT (3%)	< 100 (63% of particles)	25.7 ± 19.4 particles/g	FTIR, Raman	India	[41]
Personal care – facial cleanser/scrub	Facial scrub	PE	11–400	4,000–45,000 particles/g	FTIR	China	[26]
	Facial scrub	PE, PP, PET, ethylene acrylate copolymer	—	up to 50,391 particles/g	FTIR	China	[26]
	Facial cleanser	PE	24–600+	1.23×10^4 particles/g (average)	—	Slovenia	[28]
	Face cleansers (multiple)	PE	148–380	7.19×10^3 – 2.89×10^4 particles/g	—	Vietnam	[29]
	Facial exfoliating cleanser	—	272	0.09 particles/g?	—	—	[30]
	Facial scrub (nanoplastics)	PE (including nanoplastics)	0.024–0.052 (24–52 nm)	—	SEM, DLS	Canada	[32]
Personal care – body scrub/wash	Body scrub	PE	71.3 (mean)	6.25×10^5 – 1.19×10^6 particles/g	—	Slovenia	[28]
	Shampoo, conditioner, body wash, hand wash, face wash, soap	Acrylates, Polyquaternium, Styrene/Acrylates, PE, PP	—	181–286 particles/product (count)	—	—	[24]
Personal care – oral health products	Oral health products (toothpaste, mouthwash)	PE microbeads	—	—	—	—	[14]
Personal care – cosmetics general	Cosmetics, face wash, scrubs	PE, others	—	—	—	Sri Lanka	[15]

Product category	Specific product	Polymer type	Size (μm)	Concentration	Detection method	Country	Reference
Synthetic textiles	Towels, bathrobes (laundry)	Polyester, nylon	< 100 (fiber length), < 20 (diameter)	1,000–10,000 fibers/L wash	—	UK	[11, 25]
Plastic accessories	Shower curtains, PVC pipes, toothbrushes, dental floss	PE, PA, PET, PBT	< 100 (63% of particles)	Toothbrush: 38.2 ± 29.5 particles/brush; Dental floss: 1.3 ± 1.3 p/cm	FTIR, Raman	India	[41]
Airborne MPs in bathroom	Bathroom air	PE, PP	—	10–30 particles/m³	μ-FTIR	China	[35]
Wastewater & WWTP studies	WWTP effluent (general, not product-specific)	—	—	Removal efficiency reported	—	USA	[31]
	WWTP (advanced treatment)	—	—	> 95% removal	—	—	[37]
	WWTP (global review data)	—	—	80–99% removal for > 300 μm; <70% for < 100 μm	—	—	[38]
General personal care (concentration ranges)	Personal care products (multiple)	—	—	0.5 ± 0.3% w/w	—	—	[33]
	Personal care products (multiple)	—	—	8.60 ± 0.26% w/w	—	—	[34]
	Personal care products (mass estimate)	—	—	1.4 billion g/year emission estimate	—	India	[23]
WWTP – general (Iran)	WWTP effluent	—	—	—	—	Iran	[36]

3.2. MPs in Synthetic Bathroom Textiles

Four studies specifically examined microfiber release from synthetic bathroom textiles (towels, bath mats, shower curtains). Polyester and nylon were the most common fiber types. Napper & Thompson [25] reported that a single wash cycle of synthetic fabrics can release between 1,000 and 10,000 microfibers per liter of wastewater. These fibers were predominantly < 100 μm in length and < 20 μm in diameter, with conventional wastewater treatment plants (WWTPs) retaining < 80% of fibers. The remaining fibers were discharged into receiving waters.

3.3. MPs from Plastic Packaging and Containers

Three studies addressed MP release from plastic packaging of bathroom products. No study directly quantified MP release from packaging under real-use conditions. However, two studies inferred that PP, PE, and PET containers degrade over time into secondary MPs, particularly when exposed to heat and mechanical stress. The UNEP (2021) report [12] estimated that packaging accounts for approximately 40% of global plastic waste, with personal care products contributing a notable fraction.

3.4. MPs from Plastic Accessories and Fixtures

Only one study [36] discussed potential MP release from bathroom accessories (e.g., showerheads, PVC pipes). No experimental quantification of MP release from these sources was identified in the included studies. The review therefore identified a critical

knowledge gap regarding MP emissions from plastic fixtures.

3.5. Emission Pathways to Wastewater

Across all 26 studies, wastewater discharge was identified as the primary pathway for MPs from bathroom products into the environment. Three studies [44,45,46] tracked MP transport from domestic drains to WWTPs. Carr et al. [31] demonstrated that MPs < 300 μm bypass primary treatment stages, with removal efficiencies of 80–99% for larger particles but < 50% for particles < 50 μm.

Airborne MP emissions from bathrooms were reported in two studies. Geng et al. [35] detected airborne MPs in bathroom air at concentrations of 10–30 particles/m³, with PE and PP being the dominant types. Personal care products (e.g., powders, sprays) and deteriorating plastic accessories were identified as sources, but quantitative emission estimates were lacking.

3.6. Removal Efficiency in Wastewater Treatment Plants

Nine studies reported MP removal efficiencies in WWTPs. Conventional primary and secondary treatment removed 60–90% of MPs by particle count, but removal was highly size-dependent. Particles < 100 μm showed significantly lower removal (< 70%) compared to particles > 300 μm (> 90%). Advanced treatment (e.g., membrane bioreactors, tertiary filtration) achieved > 95% removal but was not common in the facilities studied.

None of the included studies specifically calculated removal efficiency for MPs originating exclusively from bathroom sources versus other domestic sources.

3.7. Management Challenges

Six studies discussed challenges in managing bathroom-derived MPs. The most frequently cited challenges were: (1) lack of standardized detection methods for complex product matrices, (2) absence of labeling requirements for MP-containing products, (3) limited public awareness of MP sources in bathrooms, and (4) inadequate recycling infrastructure for small-format bathroom plastics (e.g., toothbrushes, razor handles).

4. Discussion

4.1. Summary of main findings

This systematic review synthesizes evidence from 26 studies on microplastic (MP) emissions from bathroom-related products. Three main findings emerge. First, polyethylene (PE) and polypropylene (PP) are the dominant polymers, detected in 73% of studies, with particle sizes predominantly in the range of 50–500 μm and concentrations varying from 10^2 to 10^6 particles per gram of product. Second, wastewater discharge is the principal pathway for MPs from bathrooms to the environment, with conventional wastewater treatment plants (WWTPs) removing fewer than 70% of particles smaller than 100 μm. Third, while personal care products (especially facial scrubs and toothpaste) have been the most studied source, synthetic bathroom textiles (towels, bath mats) and plastic packaging are consistently identified as additional, often overlooked, sources. Critically, no included study quantified MP release from plastic bathroom fixtures (e.g., showerheads, PVC pipes) under real-use conditions, representing a major knowledge gap.

4.2. Comparison with previous reviews

Previous reviews have largely focused on either cosmetics and personal care products in isolation (e.g., Kukkola et al., 2024; Thomas et al., 2025)[12, 42, 43] or on laundry-derived microfibers (Napper & Thompson, 2022)[25]. By contrast, the present review adopts a holistic bathroom-centric perspective, integrating three source categories: rinse-off personal care products, synthetic textiles, and plastic packaging/accessories. While Kukkola et al. (2024) [12]highlighted the neglect of leave-on cosmetics, our review shows that even for rinse-off products, data on emission factors from bathroom textiles and packaging are sparse. Furthermore, unlike earlier scoping reviews (Thomas et al., 2025)[43] that included only 14 studies, our systematic approach with 26 studies provides a more robust evidence base. Importantly, no previous review has specifically linked bathroom-derived MPs to the performance of WWTPs in arid or semi-arid regions, where water reuse is common – a gap that the present review explicitly identifies.

4.3. Limitations of the included studies and of this review

The strength of our synthesis is constrained by several limitations inherent to the included studies. First, methodological heterogeneity is substantial: extraction protocols vary (water dissolution vs. acid digestion), units of measurement are inconsistent (particles/g, particles/mL, % w/w), and polymer verification is not always performed (nine of 26 studies lacked chemical confirmation). Second, most studies concentrate on a few product categories (facial cleansers, toothpaste) while neglecting others (shampoo bars, liquid soaps, plastic toothbrush handles). Third, only four studies reported both particle number and mass, hampering accurate mass-flow estimations. Fourth, geographical coverage is skewed: the majority of studies originate from China, Malaysia, India, and Europe, with no data from the Middle East (including Iran) or Africa, despite high consumption of personal care products in these regions. Fifth, none of the included studies assessed MP release from bathroom plastic accessories (shower curtains, PVC pipes, showerheads) under realistic hot-water or mechanical stress conditions. Consequently, our review cannot quantify the contribution of these sources, and the emission estimates presented in Section 3 should be interpreted as lower bounds.

4.4. Implications for wastewater management and human exposure

The finding that conventional WWTPs remove < 70% of particles < 100 µm has direct practical implications. Because most MPs from bathroom products fall into this size range (50–500 µm, with a substantial fraction < 100 µm), a large proportion bypasses primary and secondary treatment and is discharged into rivers, lakes, or coastal waters. This aligns with earlier reports that WWTP effluents are a continuous point source of MPs (Carr et al., 2016; Talvitie et al., 2017). Advanced treatment technologies (membrane bioreactors, tertiary filtration) achieve > 95% removal but are not universally installed. For regions practicing wastewater reuse – such as the Middle East – the incomplete removal of bathroom-derived MPs raises concerns about accumulation in reclaimed water used for irrigation or groundwater recharge. Furthermore, airborne MP emissions from bathrooms (detected in two studies) remain underexplored; inhalation may represent an additional exposure route, particularly in poorly ventilated bathrooms, but quantitative risk assessment is not yet possible.

4.5. Knowledge gaps and future research priorities

This review identifies five critical knowledge gaps that should guide future research:

1. **Standardized methods for complex matrices** – There is no validated protocol for extracting MPs from leave-on products or from multi-material bathroom accessories. Future work should develop harmonized methods (e.g., using enzymatic digestion or density separation with $ZnCl_2$) that allow inter-study comparison.
2. **Real-world emission studies** – Controlled laboratory studies dominate; field-based quantification of MP release from shower curtains, PVC pipes, and toothbrushes under actual bathroom conditions (hot water, mechanical abrasion, humidity) is urgently needed.
3. **Geographic expansion** – No data exist from the Middle East, Africa, or South America. Comparative studies in these regions, where bathroom habits, water temperatures, and wastewater infrastructure differ markedly, would improve global generalizability.
4. **Mass-based reporting** – Future studies must report both particle counts and mass (e.g., mg/g or µg per product use) to enable meaningful environmental burden calculations and regulatory benchmarking.
5. **Biodegradable alternatives assessment** – Although several studies propose natural exfoliants or bioplastics (PLA, PHA), none have assessed their full life-cycle MP release or ecotoxicity. Research should evaluate whether “biodegradable” substitutes truly degrade in cold wastewater or marine environments.

4.6. Policy and management recommendations

Based on the synthesized evidence, three actionable recommendations emerge. First, regulators should broaden existing microbead bans to cover all intentionally added MPs in rinse-off and leave-on bathroom products, and to require labelling of polymer content. Second, investment in tertiary wastewater treatment (e.g., membrane filtration or sand filtration) should be prioritised in regions where bathroom-derived MPs are a major contributor to freshwater pollution. Third, manufacturers should phase out PE and PP microbeads in favour of natural exfoliants (apricot kernel, salt, sugar) or high-crystallinity polymers that are less prone to fragmentation, and should redesign plastic packaging to be mono-material and recyclable.

5. Conclusion

This systematic review demonstrates that bathroom-related products – particularly PE- and PP-containing personal care items, synthetic textiles, and plastic packaging – are a significant but currently underestimated source of microplastic pollution entering wastewater systems. Conventional WWTPs remove less than 70% of particles smaller than 100 µm, resulting in continuous discharge of MPs to surface waters. The lack of standardized detection methods, geographic bias towards Asia and Europe, and absence of data on plastic bathroom fixtures represent major evidence gaps.

To mitigate bathroom-derived MP pollution, a multi-stakeholder approach is required. Researchers should prioritise development of harmonised extraction protocols and field-based emission studies, especially in under-represented regions. Policymakers must extend regulatory frameworks beyond microbeads to include all intentional MPs in bathroom products and mandate eco-labelling. Industry should accelerate transition to natural exfoliants and recyclable mono-material packaging. Without these coordinated actions, MPs from bathrooms will continue to undermine water quality, aquatic ecosystem health, and potentially human well-being.

References

1. Koelmans, A.A., et al., *Risk assessment of microplastic particles.* Nature Reviews Materials, 2022. **7**(2): p. 138-152.
2. Losetty, V., et al., *Study on Microplastic Content in Cosmetic Products and Their Detrimental Effect on Human Health.* Toxic Effects of Micro-and Nanoplastics: Environment, Food and Human Health, 2024: p. 253-264.
3. Jaafarzadeh, N., et al., *Spatial distribution of microplastics in Persian Gulf marine environments.* Scientific Reports, 2025. **16**(1): p. 2165.
4. Jahedi, F., et al., *From pollution to palpitations: the heart's silent battle with microplastics.* BMC Cardiovascular Disorders, 2025. **25**(1): p. 837.
5. Ali, N., et al., *Insight into microplastics in the aquatic ecosystem: Properties, sources, threats and mitigation strategies.* Science of The Total Environment, 2024. **913**: p. 169489.
6. Rafa, N., et al., *Microplastics as carriers of toxic pollutants: Source, transport, and toxicological effects.* Environmental pollution, 2024. **343**: p. 123190.
7. Lim, X., *Microplastics are everywhere—but are they harmful.* Nature, 2021. **593**(7857): p. 22-25.
8. Zitko, V. and M. Hanlon, *Another source of pollution by plastics: skin cleaners with plastic scrubbers.* Marine pollution bulletin, 1991. **22**(1): p. 41-42.
9. Fendall, L.S. and M.A. Sewell, *Contributing to marine pollution by washing your face: microplastics in facial cleansers.* Marine pollution bulletin, 2009. **58**(8): p. 1225-1228.
10. Gregory, M.R., *Plastic 'scrubbers' in hand cleansers: a further (and minor) source for marine pollution identified.* Marine pollution bulletin, 1996. **32**(12): p. 867-871.
11. Napper, I.E. and R.C. Thompson, *Microfibre Shedding from Textiles during Laundering: Different quantification methods but common findings*, in *Polluting Textiles*. 2022, Routledge. p. 135-152.
12. Kukkola, A., et al., *Beyond microbeads: Examining the role of cosmetics in microplastic pollution and spotlighting unanswered questions.* Journal of Hazardous Materials, 2024. **476**: p. 135053.
13. Giustra, M., et al., *Microplastics in Cosmetics: Open Questions and Sustainable Opportunities.* ChemSusChem, 2024. **17**(22): p. e202401065.
14. Singh, A. and B.K. Mishra, *Microplastic in personal care products: An overlooked environmental concern.* Journal of Cleaner Production, 2023: p. 139082.
15. GAMAGE, S.G., *OCCURRENCE OF MICROPLASTICS AND METALS IN SELECTED PERSONAL CARE PRODUCTS (PCP's) AND COSMETIC PRODUCTS IN SRI LANKA*. 2022, THE OPEN UNIVERSITY.
16. Ammala, A., *Biodegradable polymers as encapsulation materials for cosmetics and personal care markets.* Int J Cosmet Sci, 2013. **35**(2): p. 113-24.
17. Ramachandran, M., *Application of natural fibres in terry towel manufacturing.* International Journal on Textile Engineering and Processes, 2015. **1**(1): p. 87-91.
18. Lei, K., et al., *Microplastics releasing from personal care and cosmetic products in China.* Marine Pollution Bulletin, 2017. **123**(1): p. 122-126.

19. Praveena, S.M., S.N.M. Shaifuddin, and S. Akizuki, *Exploration of microplastics from personal care and cosmetic products and its estimated emissions to marine environment: An evidence from Malaysia.* Marine Pollution Bulletin, 2018. **136**: p. 135-140.
20. Ustabasi, G.S. and A. Baysal, *Occurrence and risk assessment of microplastics from various toothpastes.* Environ Monit Assess, 2019. **191**(7): p. 438.
21. Mon, E.E. and H. Nakata. *Occurrence of microplastics in cosmetic products collected from Myanmar*. in *IOP Conference Series: Earth and Environmental Science*. 2020. IOP Publishing.
22. Habib, R.Z., et al., *Trends of microplastic abundance in personal care products in the United Arab Emirates over the period of 3 years (2018–2020).* Environmental Science and Pollution Research, 2022. **29**(59): p. 89614-89624.
23. Madhumitha, C.T., et al., *Extraction, identification, and environmental risk assessment of microplastics in commercial toothpaste.* Chemosphere, 2022. **296**: p. 133976.
24. Nawalage, N.S.K. and B.K.A. Bellanthudawa, *Synthetic polymers in personal care and cosmetics products (PCCPs) as a source of microplastic (MP) pollution.* Marine Pollution Bulletin, 2022. **182**: p. 113927.
25. Napper, I.E., et al., *Characterisation, quantity and sorptive properties of microplastics extracted from cosmetics.* Marine pollution bulletin, 2015. **99**(1-2): p. 178-185.
26. Cheung, P.K. and L. Fok, *Evidence of microbeads from personal care product contaminating the sea.* Marine Pollution Bulletin, 2016. **109**(1): p. 582-585.
27. Chang, M., et al., *Warming, temperature fluctuations and thermal evolution change the effects of microplastics at an environmentally relevant concentration.* Environmental Pollution, 2022. **292**: p. 118363.
28. Kalčíková, G., et al., *Wastewater treatment plant effluents as source of cosmetic polyethylene microbeads to freshwater.* Chemosphere, 2017. **188**: p. 25-31.
29. Dung, T.T.T., H.N. Ngoc, and N.N. Trinh, *Microbeads in exfoliating products: occurrence, abundance, and potential for water contamination in Ho Chi Minh City, Vietnam.* Discover Environment, 2024. **2**(1): p. 92.
30. Chang, M., *Reducing microplastics from facial exfoliating cleansers in wastewater through treatment versus consumer product decisions.* Marine Pollution Bulletin, 2015. **101**(1): p. 330-333.
31. Carr, S.A., J. Liu, and A.G. Tesoro, *Transport and fate of microplastic particles in wastewater treatment plants.* Water research, 2016. **91**: p. 174-182.
32. Hernandez, L.M., N. Yousefi, and N. Tufenkji, *Are There Nanoplastics in Your Personal Care Products?* Environmental Science & Technology Letters, 2017. **4**(7): p. 280-285.
33. Conkle, J.L., C.D. Báez Del Valle, and J.W. Turner, *Are We Underestimating Microplastic Contamination in Aquatic Environments?* Environ Manage, 2018. **61**(1): p. 1-8.
34. Bashir, S.M., et al., *Personal Care and Cosmetic Products as a Potential Source of Environmental Contamination by Microplastics in a Densely Populated Asian City.* Frontiers in Marine Science, 2021. **Volume 8 - 2021**.
35. Geng, Y., et al., *Individual exposure to microplastics through the inhalation route: comparison of microplastics in inhaled indoor aerosol and exhaled breath air.* Environmental Science & Technology Letters, 2023. **10**(6): p. 464-470.
36. Oveisy, N., et al., *Occurrence, identification, and discharge of microplastics from effluent and sludge of the largest WWTP in Iran—South of Tehran.* Water Environment Research, 2022. **94**(8): p. e10765.
37. Ben-David, E.A., et al., *Microplastic distributions in a domestic wastewater treatment plant: Removal efficiency, seasonal variation and influence of sampling technique.* Science of The Total Environment, 2021. **752**: p. 141880.
38. Liu, W., et al., *A review of the removal of microplastics in global wastewater treatment plants: Characteristics and mechanisms.* Environment International, 2021. **146**: p. 106277.
39. De Falco, F., et al., *The contribution of washing processes of synthetic clothes to microplastic pollution.* Scientific reports, 2019. **9**(1): p. 6633.
40. Habib, R.Z., et al., *Analysis of microbeads in cosmetic products in the United Arab Emirates.* Environmental Pollution, 2020. **258**: p. 113831.
41. Protyusha, G., et al., *Microplastics in oral healthcare products (OHPs) and their environmental health risks and mitigation measures.* Environmental Pollution, 2024. **343**: p. 123118.

42. Tripathi, M., et al., *Recent technologies for transforming textile waste into value-added products: A review.* Current Research in Biotechnology, 2024. **7**: p. 100225.
43. Thomas, N.M., et al., *Microplastics in cosmetics and their impact on human health.* Discover Applied Sciences, 2025. **8**(2): p. 172.

Figures

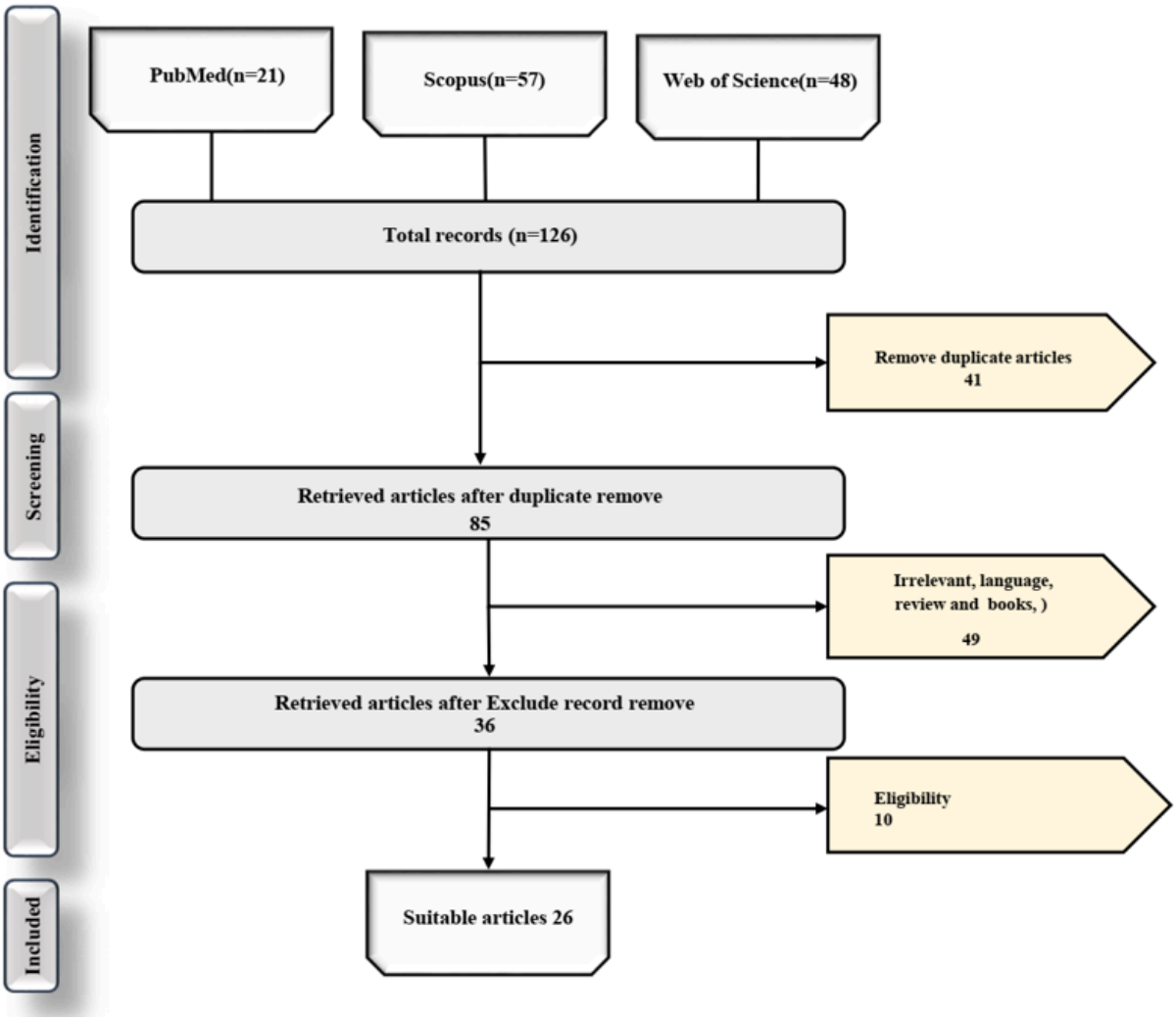


Figure 1

PRISMA Flow diagram.

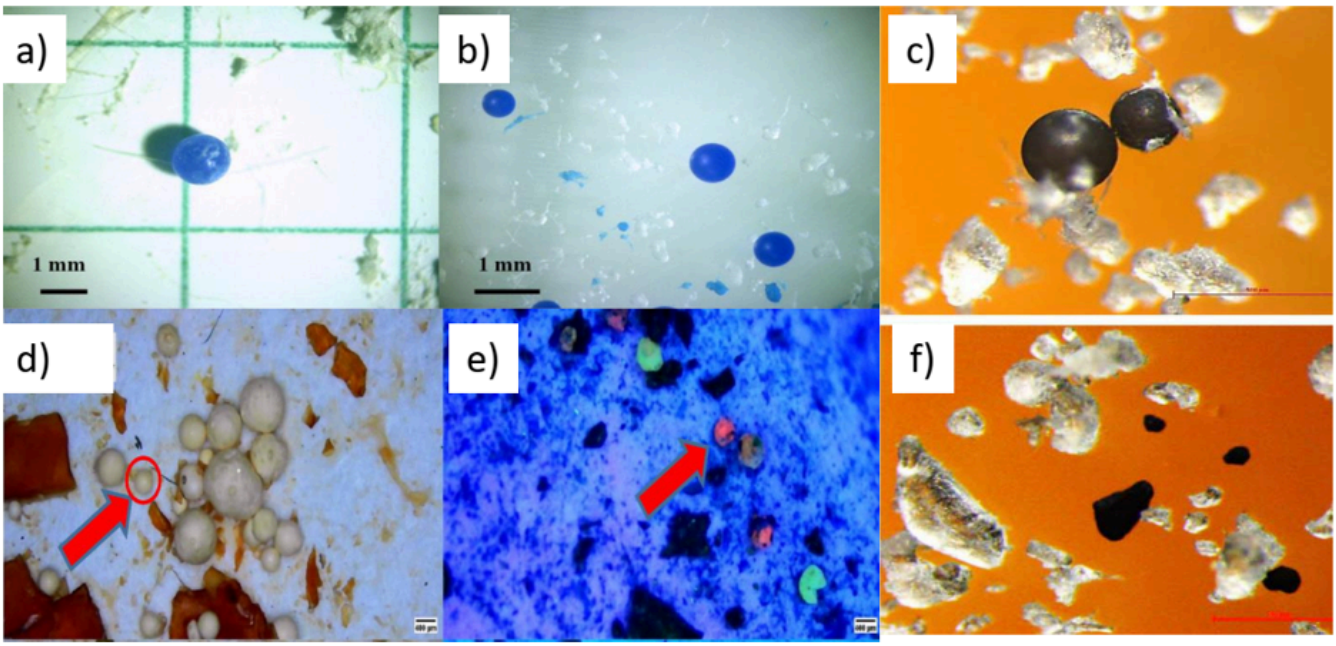


Figure 2

Original published figure of MPs in bathroom toiletries Fig a and b MPs in facial scrubbers (by Cheung and Fok.)[26], Fig C and f MPs particles in facial cleanser products reported by Kun Leia, 2017[18]. Fig d and e MPs in face wash by Sachith Gamage 2024[15]

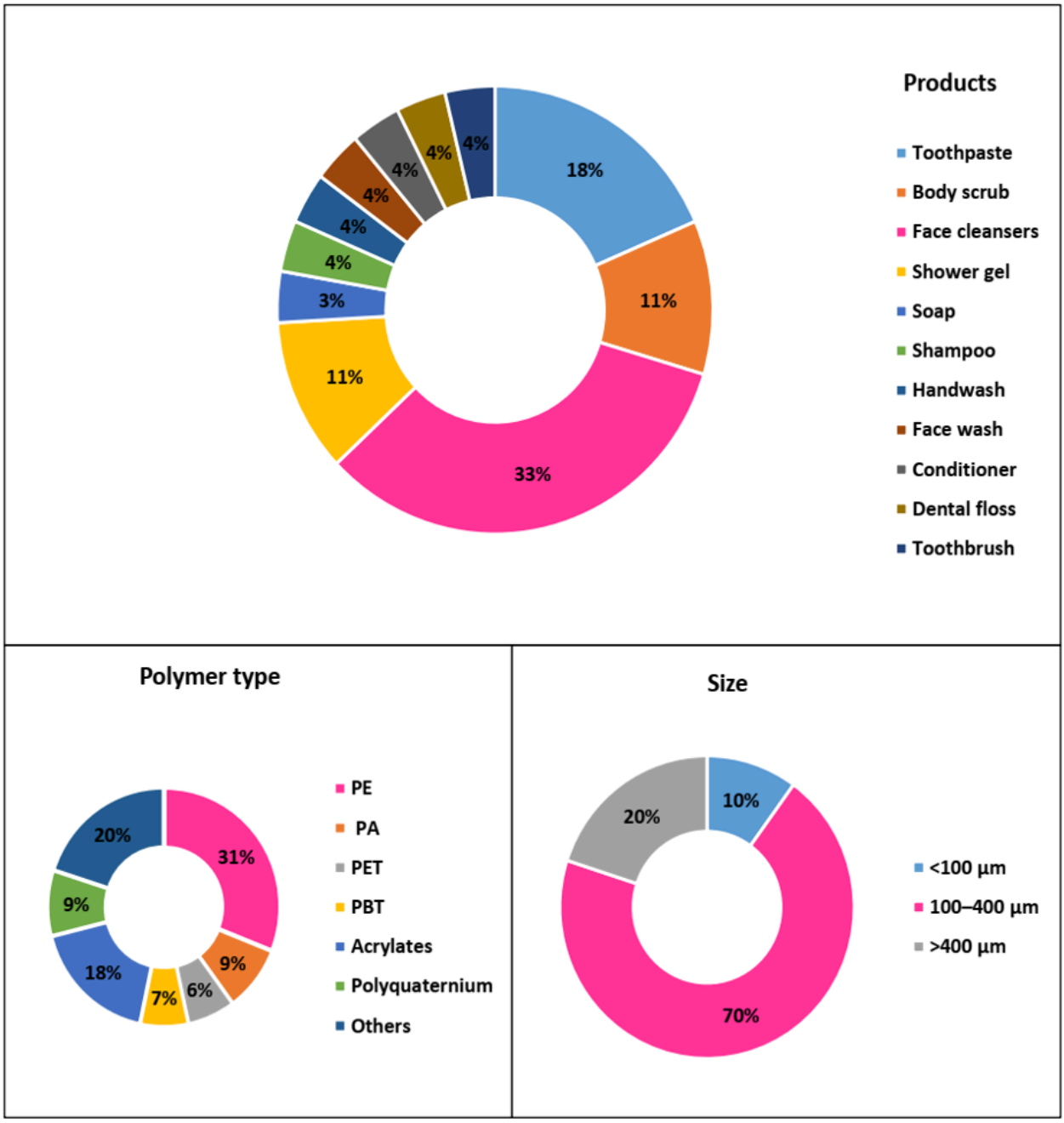


Figure 3

Analysis of MPs Composition and size in Care Products

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- GraphicalAbstract.docx