MICROPLASTICS IN TOOTHPASTE:

Scientific Evidence for Policy and Regulatory Action in Bangladesh

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Microplastics in Toothpaste: Scientific Evidence for Policy and Regulatory Action in Bangladesh

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About ESDO
Environment and Social Development Organization - ESDO is a Bangladesh-based, non-profit, non-governmental action research organization working towards a toxic-free and zero-waste planet. This involves combating pollution and building regenerative solutions through research, policy advocacy, communication initiatives, campaigns, and movement building. Since its establishment in 1990, ESDO has been working to conserve biodiversity, protect public health, and promote environmental sustainability. ESDO pioneered the anti-polythene campaign in 1990, which later contributed to the nationwide ban on polythene shopping bags in Bangladesh in 2002.

Publication Information
Publication: July 2026

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ISBN No. 978-984-35-9610-9

Acknowledgment
We express our gratitude to the Almighty for enabling us to conduct this study successfully. ESDO sincerely thanks all contributors to this study. We acknowledge the Laboratory of Environmental Health and Ecotoxicology (EHE), Department of Environmental Sciences, Jahangirnagar University, for providing laboratory facilities. We extend our appreciation to Dr. Md. Mostafizur Rahman, Professor, Department of Environmental Sciences, Jahangirnagar University, and Nahid Hasan, Research Assistant, for their technical support. We also thank the research team, field investigators, laboratory personnel, and ESDO team members, for their support.

Disclaimer

This report, "**Microplastics in Toothpaste: Scientific Evidence for Policy and Regulatory Action in Bangladesh"** has been prepared by Environment and Social Development Organization - ESDO, with laboratory analysis conducted at Laboratory of Environmental Health and Ecotoxicology (EHE), Department of Environmental Sciences, Jahangirnagar University. The content, findings, and recommendations are based on consumer survey data, laboratory analysis, key informant interviews, and policy review conducted during the study period. As the baseline study on microplastics in toothpaste products in Bangladesh, this report provides initial scientific evidence to support future research, regulatory development, and policy discussions.

While every effort has been made to ensure the accuracy, reliability, and objectivity of the information presented, the authors do not assume responsibility for any consequences arising from the use or interpretation of this information. The opinions expressed in this report reflect the authors' perspectives and do not necessarily represent the positions of any government agency, donor, partner organization, national policy decisions, or the trade names of any products.

The findings are based on scientific methods, including stereomicroscopic examination and Fourier Transform Infrared Spectroscopy (FTIR) analysis, but are not intended to replace official regulatory testing or serve as legal certification. As Bangladesh currently has no defined national limits or regulatory standards for microplastics in toothpaste products, the findings should not be interpreted as evidence of regulatory non-compliance by any manufacturer or brand. The results are intended to provide baseline scientific evidence to support future research, policy development, and the establishment of appropriate regulatory standards.

This report is intended for informational, educational, research, and advocacy purposes only. It aims to raise awareness, inform policy discussions, and contribute to the broader dialogue on consumer safety, environmental protection, and the development of regulatory standards for microplastics in toothpaste and other oral care products. Readers are advised to consult relevant national and international regulatory authorities for official standards and compliance requirements. Neither ESDO, the Laboratory of Environmental Health and Ecotoxicology (EHE), Department of Environmental Sciences, Jahangirnagar University, nor any of their representatives shall be held liable for any loss or damage arising, directly or indirectly, from the use of or reliance on this publication.

Content

Executive Summary

Microplastic pollution has emerged as a significant global environmental concern due to the widespread presence of plastic particles in water, soil, sediment, and consumer products. Microplastics, generally defined as plastic particles smaller than 5 mm, are persistent environmental contaminants that originate from the fragmentation of larger plastic debris or are intentionally manufactured for use in consumer and industrial products. They have been detected in oceans, rivers, soils, sediments, atmospheric dust, food, drinking water, and even human biological samples, highlighting their widespread distribution across environmental and biological systems. Their ability to adsorb chemical contaminants, interact with biological systems, and enter aquatic and terrestrial food webs has raised growing environmental and public health concerns. Toothpaste has received increasing international attention as a potential source of primary microplastic pollution because synthetic polymers may be incorporated into formulations and released into wastewater during routine use. Studies from the United States, Europe, China, South Korea, and other countries have confirmed the presence of microplastics in available toothpaste products, prompting several countries to introduce regulations restricting intentionally added plastic microbeads in consumer and personal care products, including toothpaste.

Despite increasing global evidence, no systematic study had previously been conducted in Bangladesh to investigate the occurrence and characteristics of microplastics in available toothpaste products. Currently, Bangladesh lacks specific regulatory standards, testing protocols, or monitoring requirements addressing microplastic content in toothpaste products. Existing regulatory frameworks, including product quality and safety standards, do not specifically address microplastic contamination. Scientific evidence is therefore needed to support the development of regulatory standards, monitoring frameworks, and policy measures. In the absence of defined national regulatory standards and permissible limits, there is currently no clear framework for assessing compliance with microplastic-related requirements in toothpaste products. To address these knowledge and regulatory gaps, the Environment and Social Development Organization - ESDO conducted a comprehensive study on microplastics in toothpaste products available in Bangladesh. The study integrated laboratory analysis, consumer surveys, and key informant interviews to generate baseline scientific evidence for regulatory development, monitoring, consumer awareness, and evidence-based policy actions on microplastics in toothpaste products in Bangladesh.

Study Design and Timeline

- **Study period:** July 2025–June 2026.
- **Study design:** Mixed-methods research comprising a consumer survey, laboratory analysis, and Key Informant Interviews (KIIs).
- **Consumer survey (September–December 2025):** A total of 2,760 respondents across Bangladesh were surveyed to assess toothpaste use practices, purchasing behaviour, and awareness of microplastics in oral care products.
- **Market assessment and toothpaste sample collection (January–February 2026):** Thirty-four available toothpaste samples representing 19 brands were collected from retail outlets, supermarkets, and wholesale markets across Bangladesh.
- **Laboratory analysis (March–June 2026):** Thirty-four toothpaste samples were analyzed using stereomicroscopy at the Laboratory of Environmental Health and Ecotoxicology (EHE), Jahangirnagar University. Representative particles were further characterized using Fourier Transform Infrared Spectroscopy (FTIR) at the Wazed Miah Science Research Center (WMSRC), Jahangirnagar University.
- **Key Informant Interviews (April–May 2026):** KIIs were conducted with representatives from relevant regulatory and research and academic institutions to assess regulatory gaps, laboratory capacity, research needs, and policy priorities.

Key Findings

Consumer Survey Findings

- A total of 2,760 respondents from diverse socioeconomic backgrounds, including different age groups, genders, educational levels, and income groups, participated in the survey to assess toothpaste use practices, purchasing behaviour, and awareness regarding microplastics in oral care products.
- The majority of respondents reported regular use of toothpaste (82.5%) and toothbrushes (90.6%).
- Regarding toothpaste use frequency, 56.9% of respondents reported using toothpaste once daily, while 40.6% reported using toothpaste twice daily.
- MediPlus was the most commonly used toothpaste brand among respondents (35.6%), followed by CloseUp (14.4%), Pepsodent (13.8%), and Colgate (11.3%).

- Awareness regarding microplastics in oral care products was limited:
    - 41.9% of respondents had never heard of microplastics in toothpaste.
    - 31.3% had heard about microplastics but were not familiar with the issue.
    - Only 26.9% reported awareness of microplastics in oral care products.

Laboratory Analysis Findings

- A total of 34 available toothpaste samples representing 19 brands were analyzed.
- Samples were collected from retail outlets, supermarkets, and wholesale markets across Bangladesh.
- The products originated from four countries: Bangladesh (25 samples), India (5), Thailand (2), and Vietnam (2).
- Microplastic particles were detected in 26 of the 34 samples (76.5%), while 8 samples (23.5%) showed no detectable microplastics.
- Microplastics were detected in products originating from all four countries: Bangladesh (22 of 25 samples), India (1 of 5 samples), Thailand (1 of 2 samples), and Vietnam (2 of 2 samples).
- Microplastic concentrations ranged from 20 to 320 particles per 100 g of toothpaste
- **The highest microplastic concentrations were detected in**
    - Mediplus Fluoride Gel (TP-15) – 320 particles/100 g
    - Close Up Red Hot (TP-03) – 160 particles/100 g
    - Closeup Menthol Fresh (TP-21) – 160 particles/100 g
    - Kodomo Ultra Shield Formula (TP-16) – 140 particles/100 g
    - Signal Green Tea (TP-07) – 120 particles/100 g
    - Pepsodent Advance Salt (TP-05) – 100 particles/100 g
    - Himalaya Complete Care (TP-30) – 100 particles/100 g
    - Sensodyne Fresh Mint (TP-06) – 80 particles/100 g
- Microplastic particles were detected in both locally manufactured and imported toothpaste products.
- Among the six toothpaste products available for children, four (66.7%) contained detectable microplastic particles: Kodomo Ultra Shield Formula (140 particles/100 g), Meril Baby (Strawberry) (60 particles/100 g), Meril Baby (Orange) (40 particles/100 g), and Pepsodent Kids (Orange) (20 particles/100 g). Parachute Just for Baby and Kodomo (Orange) showed no detectable microplastic particles.
- None of the analyzed toothpaste products explicitly declared the presence of microplastics on their product labels.

Polymer Characterization Findings

Fourier Transform Infrared Spectroscopy (FTIR) analysis was conducted on representative particles isolated from the three toothpaste samples with the highest microplastic concentrations—*Mediplus Fluoride Gel (TP-15)*, *Close Up Red Hot (TP-03)*, and *Closeup Menthol Fresh (TP-21)*. FTIR analysis confirmed that the isolated particles were synthetic plastic polymers and identified them as Low-Density Polyethylene (LDPE), Ethylene Vinyl Acetate (EVA), and High-Density Polyethylene (HDPE), respectively.

Regulatory and Stakeholder Findings

- Key Informant Interviews (KIIs) revealed that Bangladesh currently has no specific national standards or regulatory provisions addressing microplastics in toothpaste products.
- Stakeholders noted that advanced analytical instruments, including Fourier Transform Infrared Spectroscopy (FTIR) and Raman spectroscopy, are available in some laboratories for microplastic identification.
- Stakeholders highlighted that research on microplastics in Bangladesh remains limited due to inadequate funding and resource constraints.
- Existing product certification and quality control systems do not include microplastic detection, and standardized testing protocols and routine monitoring have not yet been established.
- Stakeholders acknowledged the potential environmental and public health concerns associated with microplastics and emphasized the importance of reducing unnecessary human and environmental exposure.

Stakeholders emphasized the need for

- Development of national standards and regulatory guidelines for microplastics in toothpaste.
- Establishment of standardized testing methods and routine monitoring systems.
- Strengthening laboratory capacity for microplastic detection and polymer identification.
- Improving ingredient transparency and coordination among relevant regulatory authorities.

Policy Implications and Recommendations

The findings of this study highlight the need to develop national regulatory standards and guidelines for microplastics in toothpaste products in Bangladesh. Establishing standardized testing protocols, routine monitoring systems, and strengthening laboratory capacity will be essential for effective regulation. Improved ingredient transparency and enhanced coordination among relevant regulatory authorities are also needed to support evidence-based decision-making, consumer protection, and environmental sustainability. Further large-scale research on microplastics in toothpaste and other consumer products should be encouraged to strengthen the national evidence base and inform future policy development.

1. Introduction

1.1 Background

Plastic pollution has emerged as one of the most alarming environmental challenges of the modern era. Since the large-scale commercialization of plastics in the 1950s, global plastic production has increased dramatically due to the material's affordability, durability, flexibility, and extensive industrial applications. However, the same properties that make plastics commercially valuable also make them environmentally persistent. Most conventional plastics do not biodegrade naturally and may remain in the environment for hundreds of years, gradually fragmenting into smaller particles through sunlight, weathering, abrasion, and mechanical degradation processes[1].

According to the United Nations Environment Programme (UNEP), global plastic production has reached hundreds of millions of tonnes annually, with a significant proportion becoming waste shortly after use. This waste is now ubiquitous across ecosystems, including oceans, rivers, soils, air, and even remote polar regions. Plastic debris has been documented in marine organisms, drinking water, food products, and human tissues, demonstrating that plastic pollution is no longer only an environmental issue but also a potential public health concern with global exposure pathways.[2,3]

The environmental persistence of plastics has led to increasing fragmentation into smaller particles known as microplastics. These particles are now recognized as a pervasive contaminant across ecosystems worldwide. The U.S. Environmental Protection Agency (EPA) defines microplastics as plastic particles smaller than 5 millimeters that originate either from the breakdown of larger plastic items or are intentionally manufactured for use in industrial and consumer applications[4]. Microplastics have been detected in marine and freshwater systems, sediments, atmospheric dust, food chains, and even human biological samples, indicating their widespread environmental mobility and potential for long-term ecological and health impacts.

UNEP further highlights that microplastics are now present in virtually all environmental compartments, from Antarctic ice to deep ocean ecosystems, and are increasingly being found in seafood, drinking water, table salt, and atmospheric deposition such as rainfall.[5] Their ability to transport toxic chemicals and persist in food webs has raised significant concern among scientists and policymakers regarding their ecological toxicity and potential human health risks.

Among the various sources of microplastics, personal care and cosmetic products have been identified as important contributors to primary microplastic pollution. These include products

[1] UNEP. (2023). *Turning off the Tap: How the world can end plastic pollution and create a circular economy*.
[2] Leslie, H. A., et al. (2022). Discovery and quantification of plastic particle pollution in human blood. *Environment International*, 163.
[3] Campanale, C., Massarelli, C., Savino, I., Locaputo, V., & Uricchio, V. F. (2020). A detailed review study on potential effects of microplastics and additives of concern on human health. *International Journal of Environmental Research and Public Health*, 17(4), 1212.
[4] United States Environmental Protection Agency (EPA). (n.d.). *Microplastics research*.
[5] United Nations Environment Programme (UNEP). (2018). *Single-use plastics: A roadmap for sustainability*.

such as facial scrubs, cleaning agents, and oral hygiene products like toothpaste. Certain toothpaste formulations contain intentionally added microplastic particles that serve as abrasives, polishing agents, texture enhancers, and stabilizers. Unlike macroplastic waste, these particles are directly discharged into wastewater systems immediately after use, making them a continuous and largely unregulated source of microplastic emissions into aquatic environments.

Environmental organizations such as Beat the Microbead report that synthetic polymer ingredients continue to be present in some oral care products globally despite increasing awareness and voluntary industry commitments to eliminate microplastics[6]. Similarly, consumer-focused environmental analyses highlight that microplastics in toothpaste may enter aquatic ecosystems due to insufficient removal during wastewater treatment processes[7]. Investigative discussions in scientific and policy literature also emphasize the hidden contribution of daily dental hygiene routines to microplastic pollution and the need for stronger regulatory responses.[8]

In addition to environmental concerns, emerging research indicates potential human exposure pathways through ingestion, inhalation, and dermal contact. Microplastics have been detected in various human tissues, raising concerns about long-term biological implications, although scientific understanding of health impacts is still evolving.[9,10]

Overall, the growing recognition of microplastics as a global pollutant highlights the need to examine overlooked sources, including everyday consumer products such as toothpaste. Given its universal use, even small concentrations of microplastics in toothpaste formulations may contribute significantly to cumulative environmental loading when scaled across populations.

This study, therefore, focuses on addressing this critical knowledge gap by systematically investigating microplastic contamination in widely used toothpaste brands in Bangladesh, contributing to both scientific understanding and policy-relevant evidence on emerging chemical and plastic pollution pathways.

1.2 Microplastics in Toothpaste: An Emerging Environmental Concern

Recent scientific studies from different countries have documented the presence of microplastics in commercial toothpaste brands. Research conducted in India, Europe, and other regions identified various microplastic particles in whitening toothpaste, herbal toothpaste, gel-based toothpaste, and children's oral care products (Quantification and Characterization of Microplastics in Five Popular Indian Toothpaste Brands, 2025). Detected particles have varied considerably in size, shape, color, concentration, surface texture, and polymer composition.

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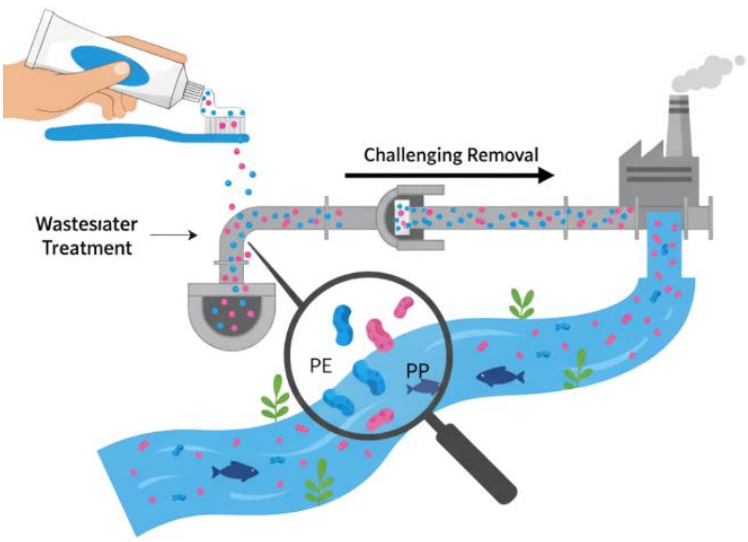
[6] Beat the Microbead. (n.d.). *Myth buster: Toothpaste still contains plastic ingredients*.
[7] Ocean Blue Project. (n.d.). *Discover harmful microplastics in toothpaste and how to avoid them*.
[8] The Conversation. (2025). *The hidden plastic problem in your daily dental routine and what's being done about it*.
[9] Nawab, A., Ahmad, M., Khan, M. T., Nafees, M., Khan, I., & Ihsanullah, I. (2024). Human exposure to microplastics: A review on exposure routes and public health impacts. Journal of Hazardous Materials Advances, 16, 100487. https://doi.org/10.1016/j.hazadv.2024.100487
[10] Abbas, G., Ahmed, U., & Ahmad, M. A. (2025). Impact of Microplastics on Human Health: Risks, Diseases, and Affected Body Systems. Microplastics, 4(2), 23. https://doi.org/10.3390/microplastics4020023

Some studies reported that whitening and cosmetic-oriented toothpaste products contained higher levels of synthetic polymer particles compared to conventional formulations. Researchers also observed that many plastic ingredients remain difficult for consumers to identify because they are listed using complex chemical terminology on packaging labels.



Scientific investigations have further shown that wastewater treatment plants are often unable to completely remove microscopic plastic particles. Consequently, toothpaste-derived microplastics may eventually enter rivers, lakes, estuaries, coastal environments, and marine ecosystems (Campanale et al., 2020).

1.3 Rationale of the Study

Although international studies increasingly document microplastic contamination in oral care products, Bangladesh lacks baseline scientific evidence on the presence and characteristics of microplastics in available toothpaste brands. There is currently no comprehensive study assessing microplastic contamination in widely used toothpaste brands available in the Bangladeshi market.

Existing gaps include:

- Absence of baseline data on microplastic contamination in toothpaste
- Limited understanding of polymer types and particle characteristics;
- Lack of information regarding product categories most associated with MPs;
- Limited awareness among consumers and policymakers;
- Insufficient regulatory preparedness regarding microplastics in oral care products; and
- Lack of stakeholder perspectives regarding risks and solutions.

The absence of baseline scientific evidence on microplastic contamination in toothpaste limits the assessment of potential environmental and public health risks and constrains the development of evidence-based regulatory measures in Bangladesh. It also restricts the ability of policymakers, regulatory authorities, researchers, manufacturers, and consumers to evaluate product safety, establish appropriate regulatory standards, and implement effective monitoring and risk management strategies.

This study therefore aims to systematically detect and characterize microplastic contamination in widely used toothpaste brands available in Bangladesh. The findings will generate baseline scientific evidence to support evidence-based policymaking, strengthen consumer protection, and inform the development of national regulatory standards, product quality guidelines, and monitoring mechanisms for microplastics in toothpaste and other oral care products.

1.4 Why This Study Matters: Environmental, Health, Scientific, and Policy Significance

The issue of microplastic contamination in toothpaste and oral care products extends far beyond a simple product safety concern. It intersects with broader environmental pollution, public health protection, sustainable consumption, chemical governance, and plastic reduction efforts. As toothpaste is a universally used daily product, even small concentrations of microplastics within individual products may collectively contribute to substantial environmental release and long-term human exposure when multiplied across millions of consumers.

In Bangladesh, where challenges related to plastic waste management, wastewater treatment, river pollution, and environmental monitoring are already significant, the absence of scientific evidence regarding microplastics in oral care products represents a critical knowledge gap. This study therefore, holds considerable importance from environmental, scientific, public health, consumer protection, and policy perspectives.

Scientific Significance: Generating Baseline Evidence for Bangladesh

Despite increasing international research on microplastics, there remains a severe lack of scientific evidence regarding microplastic contamination in toothpaste products available in Bangladesh. Currently, no comprehensive dataset exists assessing:

- The presence of microplastics in widely used toothpaste brands;
- The concentration and abundance of particles;
- Particle size distribution;
- Shape and morphology;
- Color variation;
- Polymer composition;
- Differences across product categories and formulations.

This absence of baseline data significantly limits scientific understanding of product-related microplastic pollution within the Bangladeshi context.

The present study is therefore scientifically important because it will provide one of the first systematic assessments of microplastic contamination in toothpaste products sold in Bangladesh. Through laboratory-based detection and characterization, the study will generate baseline scientific evidence on the occurrence, abundance, particle size distribution, morphology, color, polymer composition, and contamination patterns across different toothpaste categories and formulations.

The research may further contribute to the growing global body of literature on primary microplastics in personal care products and support future comparative studies across countries and product categories. They may also strengthen research capacity in Bangladesh in emerging fields such as environmental toxicology, plastic pollution science, consumer product safety assessment, wastewater contamination research, and environmental chemistry. Furthermore, the study may also serve as a foundation for future multidisciplinary investigations on microplastic exposure pathways, ecological impacts, and risk assessment in Bangladesh.

1.5 Study Objectives

General Objective

To detect and characterize microplastics in toothpaste products available in Bangladesh to generate scientific evidence for the development of regulatory standards and policy measures scientific evidence for the development of regulatory standards

Specific Objectives

- To determine the presence and concentration of microplastic particles in selected toothpaste products available in Bangladesh
- To characterize detected microplastic particles based on morphology and polymer composition
- To compare microplastic contamination levels among different toothpaste brands and product categories, including children's toothpaste
- Assess consumer awareness, knowledge, and practices related to toothpaste use and microplastics in oral care products
- Explore stakeholder perspectives on regulatory frameworks, laboratory capacity, and challenges related to microplastic monitoring in toothpaste
- To explore stakeholder perspectives on existing regulatory frameworks, laboratory capacity, and challenges related to microplastic monitoring in toothpaste products
- To provide scientific evidence and recommendations to support the development of regulatory standards for microplastics in toothpaste products in Bangladesh.

2. Microplastics in Toothpaste: Sources, Characteristics, and Global Perspectives

2.1 Understanding Microplastics: Tiny Particles, Massive Consequences

Microplastics (MPs) are generally defined as plastic particles measuring less than 5 millimeters in size. These particles may be visible to the naked eye or microscopic in nature and can originate from a wide range of consumer, industrial, and environmental sources.[11] Due to their small size and persistence, microplastics can travel through air, water, soil, food chains, and biological systems with relative ease[12].

[11] U.S. Environmental Protection Agency (EPA), *Microplastics Research*, Water Research Program. Available at: https://www.epa.gov/water-research/microplastics-research (Accessed: May 2026).
[12] Prata, J. C., da Costa, J. P., Lopes, I., Duarte, A. C., & Rocha-Santos, T. (2020). Environmental exposure to microplastics: An overview on possible human health effects. *Science of the Total Environment*, 702.

Types of Microplastics

Microplastics are commonly categorized into two major groups:

1. Primary Microplastics

Primary microplastics are intentionally manufactured small plastic particles designed for direct use in commercial products. These are produced in microscopic sizes for specific industrial or cosmetic purposes and are commonly found in:

- Personal care products;
- Toothpaste and oral hygiene products;
- Facial scrubs and exfoliants;
- Cosmetic products;
- Industrial abrasives;
- Synthetic textile fibers;
- Cleaning products;
- Paints and coatings.

Primary microplastics are especially concerning because they are directly released into wastewater systems during product use without undergoing solid waste management or recycling processes[1].

2. Secondary Microplastics

Secondary microplastics originate from the breakdown of larger plastic materials such as plastic bags, bottles, fishing nets, packaging materials, tires, and synthetic fabrics. Environmental exposure to sunlight, ultraviolet radiation, wave action, oxidation, and mechanical stress gradually fragments larger plastics into microscopic particles over time (Campanale et al., 2020).

Classification Based on Shape and Morphology

Microplastics are further classified according to their physical shape and morphology, including:

- **Fragments:** Irregular broken plastic particles generated through degradation;
- **Fibers:** Thin elongated particles commonly originating from synthetic textiles and ropes;
- **Films:** Thin sheet-like particles from packaging materials;
- **Pellets or Beads:** Spherical particles intentionally manufactured for industrial or cosmetic use;
- **Foams:** Lightweight porous particles derived from expanded plastics;
- **Granules:** Small abrasive particles used in personal care products.

Studies on personal care products and toothpaste frequently identify microplastic fragments, beads, granules, and irregular abrasive particles composed of synthetic polymers (Chang, 2015).

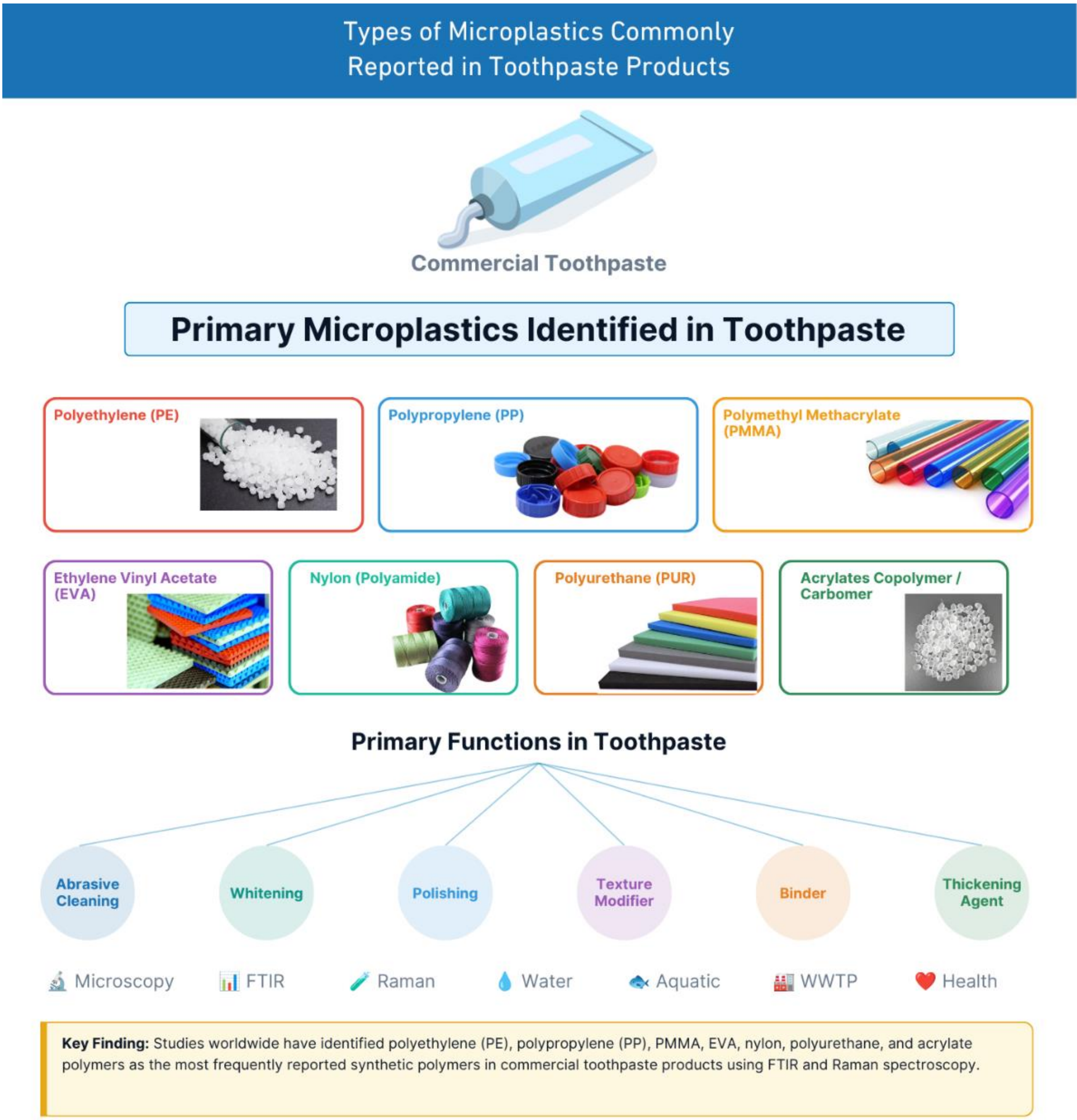
Common Polymer Types Found in Toothpaste

Scientific investigations have identified several synthetic polymers in oral care products, including:

- Polyethylene (PE);
- Polypropylene (PP);
- Polyethylene terephthalate (PET);
- Ethylene Vinyl Acetate (EVA)
- Nylon;
- Polymethyl methacrylate (PMMA);

- Polyurethane (PUR);
- Acrylate’s copolymer;
- Polyethylene oxide (PEO).

These materials are often added to improve texture, abrasiveness, polishing efficiency, whitening properties, product consistency, or shelf stability (Campanale et al., 2020).



2.2 Toothpaste as a Hidden Source of Microplastic Pollution

While large plastic waste such as bottles and packaging receives significant public attention, less visible sources of plastic pollution often remain overlooked. Personal care and cosmetic products are increasingly recognized as important contributors to primary microplastic pollution because many products contain intentionally added synthetic polymer particles.

Toothpaste is one of the most frequently used hygiene products globally, with individuals typically using it multiple times daily throughout their lives. Certain toothpaste formulations contain microscopic plastic particles that function as:

- Abrasive agents for cleaning teeth;
- Whitening agents;
- Polishing materials;
- Texture enhancers;
- Thickening or binding agents;
- Decorative particles in gel formulations.

Unlike larger plastic waste items that may enter recycling systems, toothpaste-derived microplastics are rinsed directly into sinks and drainage systems immediately after use. This creates a continuous and largely uncontrolled release pathway into wastewater systems and aquatic ecosystems (UNEP, 2023).

Organizations such as Beat the Microbead Campaign have identified numerous oral care products worldwide that still contain synthetic plastic ingredients despite increasing public concern and voluntary corporate commitments to reduce plastic microbeads.

2.3 Global Evidence: Microplastics in Toothpaste Products

2.3.1 Toothpaste as an Emerging Source of Primary Microplastics

Although plastic pollution is often associated with visible waste such as packaging materials and single-use plastics, increasing scientific evidence indicates that toothpaste is an important yet frequently overlooked source of primary microplastics. For decades, manufacturers intentionally incorporated microscopic plastic particles into toothpaste formulations to improve abrasiveness, polishing efficiency, whitening performance, texture, and product stability. During routine brushing, these particles are rinsed directly into household drainage systems, creating a continuous pathway through which primary microplastics enter wastewater streams and, ultimately, the environment.

Recent global research demonstrates that while regulatory restrictions have reduced the use of visible polyethylene microbeads in several countries, many toothpaste formulations continue to contain synthetic polymer ingredients that either function as microplastics or degrade into microplastic particles during use. Consequently, toothpaste remains an important contributor to primary microplastic pollution despite increasing public awareness and voluntary industry commitments.

Laboratory analyses conducted worldwide have identified a diverse range of synthetic polymers in commercial toothpaste products, including polyethylene (PE), polypropylene (PP), polymethyl methacrylate (PMMA), polyethylene terephthalate (PET), ethylene-vinyl acetate (EVA), nylon (polyamide), polyurethane (PUR), acrylate copolymers, and carbomer-based polymers. These polymers have been identified using advanced analytical techniques such as Fourier Transform Infrared Spectroscopy (FTIR), Raman Spectroscopy, Raman Imaging, and Scanning Electron Microscopy (SEM), allowing accurate characterization of polymer composition, morphology, and particle size.

Microplastic particles reported in toothpaste products vary considerably in size, abundance, shape, and color, with particle sizes generally ranging from 1 µm to 500 µm. The most commonly observed morphologies include spherical microbeads, irregular fragments, flakes, granules, and angular particles, reflecting differences in formulation technologies among manufacturers[15,16].

2.4 Country-wise Evidence of Microplastic Contamination in Toothpaste Products

United States: Early Recognition of Plastic Microbeads in Oral Care Products

The United States was among the first countries to identify toothpaste as a source of intentionally added microplastics. Early investigations reported widespread use of **polyethylene microbeads** as polishing and abrasive agents in commercial toothpaste formulations[14]. These spherical particles, typically ranging between **1 and 500 µm**, were designed to enhance plaque removal and improve the cleaning efficiency of toothpaste during brushing.

Environmental assessments demonstrated that virtually all microbeads used during toothbrushing are discharged directly into municipal wastewater systems, where a proportion escapes wastewater treatment and enters freshwater ecosystems. The **American Dental Association (ADA)** also highlighted concerns regarding the potential retention of polyethylene microbeads within gingival tissues, raising questions about localized irritation and oral health implications.

Growing environmental awareness and scientific evidence ultimately supported national legislative action, leading to restrictions on intentionally added plastic microbeads in rinse-off personal care products.

Europe: From Microbeads to Hidden Synthetic Polymers

European studies have documented a significant transition in toothpaste formulations following regulatory actions targeting plastic microbeads. Although visible polyethylene microbeads have become less common, investigations reveal that numerous products continue to contain synthetic polymer ingredients marketed under technical chemical names rather than being identified explicitly as plastics.

Ingredient surveys conducted across European markets, particularly in Poland, found that many toothpaste products labelled as **"microplastic-free"** still contained polymers such as **acrylates copolymer, carbomer, polyethylene derivatives, and other synthetic materials** that may contribute to environmental microplastic pollution.

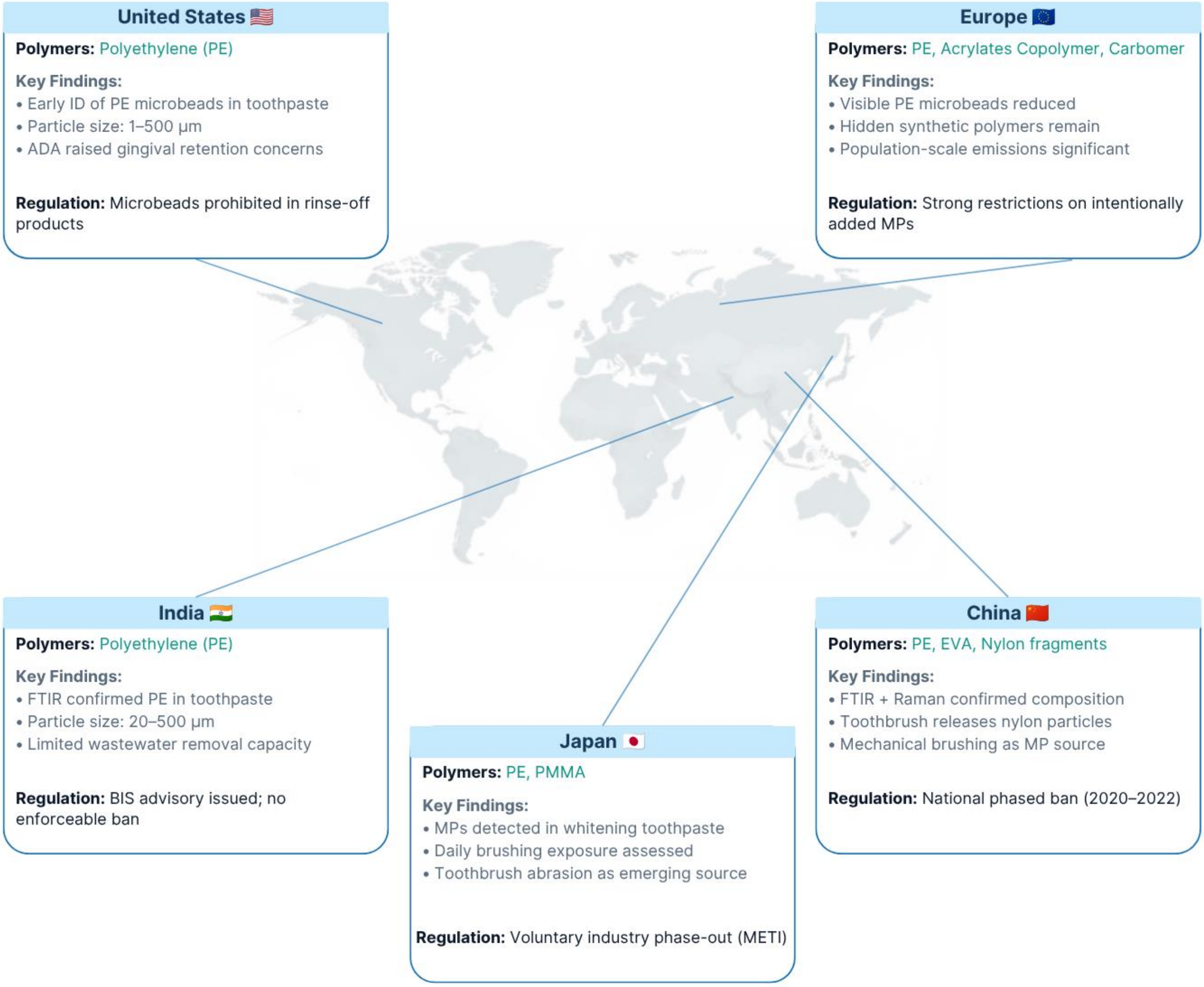
European reviews further emphasize that the cumulative environmental burden associated with toothpaste-derived microplastics remains substantial because toothbrushing is a universal daily activity. Even products containing relatively low concentrations of synthetic polymers can collectively generate considerable emissions when multiplied across millions of consumers (European Life-Cycle Assessment Reports, 2021).

India: Extensive Laboratory Evidence from Commercial Toothpaste Brands

India has produced some of the most comprehensive scientific evidence regarding microplastics in toothpaste products. A landmark study by Madhumitha et al. (2022) analyzed commercially available toothpaste brands using **Fourier Transform Infrared Spectroscopy (FTIR)** and confirmed the presence of polyethylene microplastics in multiple products. Detected particles ranged from approximately 20 to 500 µm and consisted predominantly of irregular fragments and microbeads exhibiting diverse colors and morphologies[16].

Expanding upon these findings, Protyusha et al. (2024) conducted a nationwide assessment of oral care products and concluded that microplastics remain widespread across commercially available toothpaste formulations despite growing international concern. The study further highlighted that limited wastewater treatment capacity in many urban areas increases the likelihood that toothpaste-derived microplastics enter rivers and other freshwater systems without effective removal.

Although the Bureau of Indian Standards (BIS) issued advisory guidance concerning plastic ingredients in cosmetic and oral care products in 2017, researchers noted that enforceable nationwide regulations specifically addressing intentionally added microplastics remain limited.



Summary: Polyethylene (PE), polypropylene (PP), PMMA, EVA, nylon, polyurethane, and acrylate polymers have been identified as the most frequently reported synthetic polymers in commercial toothpaste products worldwide using FTIR and Raman spectroscopy.

China: Scientific Monitoring Accompanied by Regulatory Action

China has undertaken extensive investigations into microplastics associated with oral care products while simultaneously implementing regulatory measures to reduce their environmental release.

Surveys of commercially available toothpaste products identified polyethylene (PE) and ethylene-vinyl acetate (EVA) as dominant synthetic polymers present in multiple formulations. Polymer identification was confirmed using both FTIR and Raman Spectroscopy, providing robust analytical evidence of synthetic polymer occurrence.

In parallel, studies by **Fang et al. (2023)** and **Aytulun et al. (2025)** demonstrated that routine toothbrushing also generates microplastic particles through mechanical abrasion of nylon toothbrush bristles. Raman spectroscopy confirmed continuous release of microscopic nylon fragments during simulated brushing, suggesting that oral hygiene practices contribute microplastics from both toothpaste and toothbrushes simultaneously.

Recognizing these environmental risks, the **Government of China** implemented phased restrictions on intentionally added plastic microbeads in rinse-off cosmetic products between 2020 and 2022.

Japan: Voluntary Industry Action and Emerging Scientific Evidence

Research conducted in Japan similarly demonstrates the occurrence of synthetic polymers in toothpaste products, particularly formulations marketed for whitening, polishing, and cosmetic enhancement.

Studies identified polyethylene (PE) and polymethyl methacrylate (PMMA) in several commercially available toothpaste brands. Additional investigations by the Japan Consumer Affairs Review (2022) documented synthetic polymers across multiple rinse-off cosmetic categories, confirming that oral care products remain a potential source of primary microplastics.

More recently, a study evaluated human exposure to microplastics during routine oral hygiene activities and highlighted toothpaste use as a continuous pathway for low-level daily exposure. Complementary observations by the Japan Microplastic Research Council (2021) further suggested that toothbrush abrasion may contribute additional microplastic particles, although quantitative evidence remains limited.

Rather than introducing legally binding prohibitions, Japan has primarily relied on voluntary industry commitments coordinated through the Ministry of Economy, Trade and Industry (METI) to encourage manufacturers to phase out intentionally added microplastics from rinse-off personal care products.

2.5 Global Patterns and Regulatory Developments

Collectively, international research demonstrates several consistent trends regarding microplastic contamination in toothpaste products.

First, polyethylene remains the most frequently detected polymer, although manufacturers increasingly employ alternative synthetic materials such as polypropylene, polymethyl methacrylate, ethylene-vinyl acetate, nylon, acrylate copolymers, and carbomer-based polymers as functional ingredients.

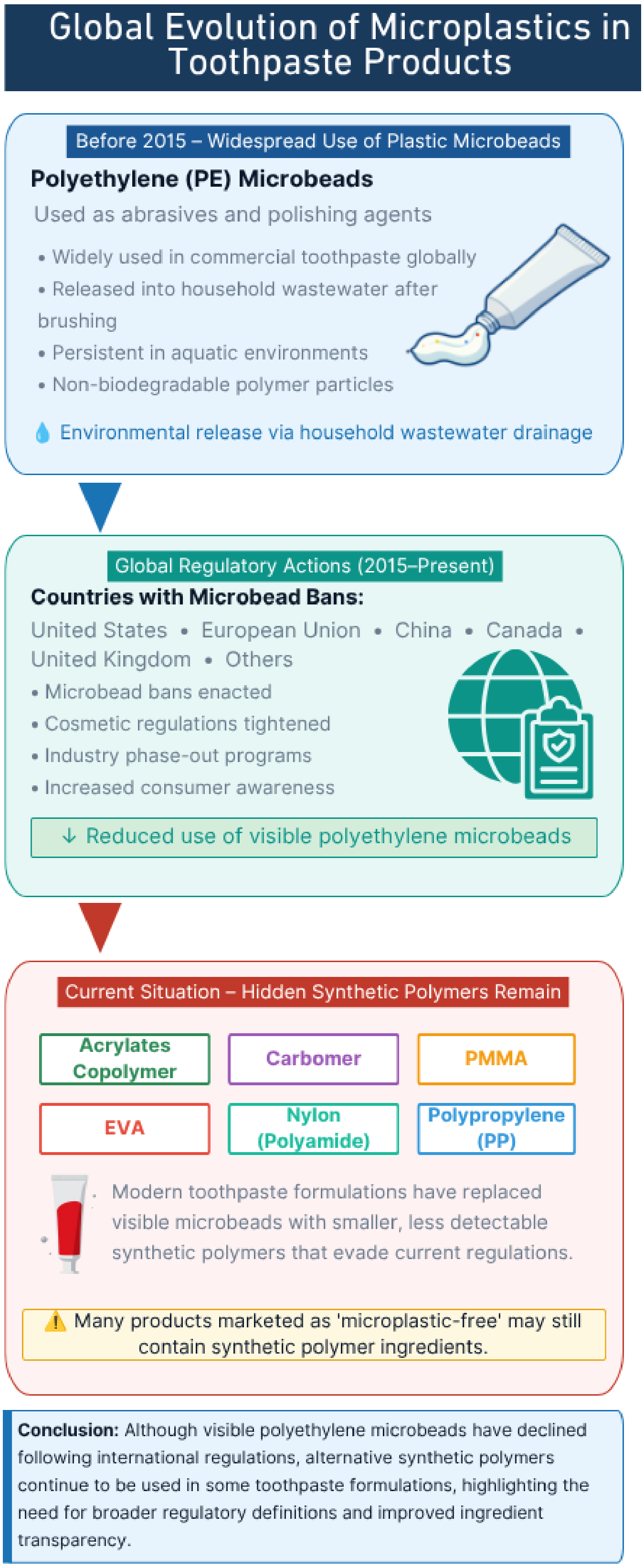
Second, microplastic particles identified in toothpaste display substantial variation in size, morphology, abundance, and polymer composition, with particle sizes typically ranging between **1 and 500 µm**. Common particle morphologies include spherical microbeads, fragments, flakes, irregular granules, and angular particles.

Third, advances in analytical techniques, including FTIR spectroscopy, Raman spectroscopy, Raman imaging, SEM, and micro-FTIR, have significantly improved the detection and characterization of microplastics in increasingly complex toothpaste formulations.

Table 1. Summary of Global Evidence on Microplastics in Toothpaste

Country	Major Polymer(s)	Detection Method	Regulatory Status
USA	PE	FTIR	Microbeads banned
Europe	PE, Acrylates, Carbomer	FTIR, Raman	Strong restrictions
China	PE, EVA	FTIR, Raman	National ban
Japan	PE, PMMA	FTIR	Voluntary phase-out

Finally, global evidence suggests that while many countries have reduced or eliminated intentionally added polyethylene microbeads through legislation or voluntary industry commitments, the continued use of alternative synthetic polymers means that toothpaste remains an important and often underestimated source of primary microplastic pollution. These findings underscore the need for clearer regulatory definitions, transparent ingredient labeling, standardized analytical protocols, and continued monitoring of oral care products to safeguard both environmental and public health.



3. Regulatory and Policy Framework for Microplastics in Toothpaste

3.1 National Regulatory Framework against microplastic adulteration in toothpaste

There are no specific restrictions against microplastic use in the manufacturing of toothpaste in Bangladesh. However, there is legislation for safe production and distribution of oral-care items, including toothpaste.

Drugs and Cosmetics Act, 2023

The Drugs and Cosmetics Act 2023 (Act No. 29 of 2023) govern the manufacture, import, sale, and quality control of cosmetics and oral-care products in Bangladesh. It was formed to replace the Drugs Act 1940 and Drugs (Control) Ordinance 1982.[13] The Act authorizes the Directorate General of Drug Administration (DGDA) to regulate both drugs and cosmetics marking a significant shift from previous arrangements in which the Bangladesh Standards and Testing Institution (BSTI) had a larger oversight role.[14]

Import Policy Order (2021-24)

The policy mandates any importer to obtain a Technical Clearance Certificate from the BSTI to import toothpaste.[15] Yet, the technical clearance does not check for the presence of microplastics in oral-care products, such as toothpastes. It also does not mandate the requirement of adding microbead labeling on these

[13] Drugs and Cosmetics Act 2023
[14] Ibid.
[15] Import Policy Order 2021–2024, SRO No 92-Law/2022

products. Therefore, the policy completely misses out on verifying oral-care products to be free of microplastics.

Bangladesh Standards and Testing Institution (BSTI) Standards

Bangladesh Standards and Testing Institution (BSTI) is the governmental body in charge of setting standards and enforce regulations, and testing products to ensure consumer safety and the quality of products supplied nation-wide. For imported toothpaste, the Bangladesh Trade Portal lists a mandatory requirement for a BSTI Conformity Certificate under national standard BDS 1216:2006, covering quality, safety, and labelling specifications.[16] However, the certificate does not necessarily indicate the absence of microplastics in the toothpastes as neither the Drugs and Cosmetics Act 2023 nor BSTI standards explicitly forbid the addition of microplastics in toothpaste manufacturing.

Bangladesh Environmental Conservation Act, 1995 & Amendments

This Act grants the Department of Environment the authority to impose

bans on materials that cause pollution and ecological degradation.[17] Section 6A of the amended Bangladesh Environment Conservation Act of 2002 states that if any article is harmful to the environment, the Government may issue a direction imposing absolute ban on its manufacture, import, marketing, sale, demonstration for sale, stock, distribution, commercial carriage or commercial use, or allow the operation or management of such activities under conditions specified in the notification.[18]

Despite a clearly designed law against environmentally harmful substances, the ban on using microplastics or microbeads in toothpastes is far from being enacted. Though the Act distinguished and banned polyethylene and polypropylene products due to their harmful effects on environment and human health, it does not specifically consider the hazards caused by microplastics in oral-care products.

3.2 International Regulatory and Policy Developments and Global Initiatives

International Legally Binding Instrument on Plastics Pollution (INC)

The Global Plastics Treaty is an international effort to address the growing global issue of plastic pollution. It requires governments to handle the whole lifespan of plastics in a comprehensive, legally binding manner. The Intergovernmental Negotiating Committee on Plastic Pollution (INC) is responsible for conducting negotiations on the Global Plastic Treaty. From INC 1 to INC 5.3, the INC process has struggled for six years to come to a consensus on how to manage plastic waste and lessen plastic pollution. In August 2025, the last round of negotiations (INC-5.2) took place in Geneva, Switzerland; as of right now, no worldwide

[16] Bangladesh Standards and Testing Institution (BSTI), *Toothpaste: Standards and Conformity Certificate Requirement* (Dhaka: BSTI, 2022).
[17] Bangladesh Environment Conservation Act 1995
[18] Ibid

agreement has been reached.[19] INC 5.3 was recently held on 7 February 2026 in Geneva, Switzerland to elect a new chair for the Global Plastics Treaty.[20]

Bangladesh's national laws and policies deal with plastic control in a disjointed way, lacking specific objectives for circularity and the monitoring and management of the plastic lifecycle. The INC method, on the other hand, promotes a comprehensive strategy that incorporates into national policy the entire life cycle of plastic products, from manufacture through distribution and import to consumption and disposal. It demands unified reporting standards, worldwide commitment and accountability, not yet reflected in Bangladesh's present structure. Bangladesh must create enforceable targets in line with the Treaty, update and Extended Producer Responsibility (EPR).[21] These ideas are and connect its current legislation, and improve cooperation between ministries, producers, law enforcement, and other stakeholders in order to close this gap.

Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and Their Disposal

In 1989, the Basel Convention was introduced to combat the unmanaged hazardous waste dumped in developing countries. The Convention specifically addresses the management, disposal, and transboundary movements of hazardous wastes around the world. The Convention demands the reduction of the generation and transboundary movements of hazardous wastes, the management of hazardous wastes in an eco-friendly manner, and their treatment, disposal as close as possible to the source of generation, and volume reduction at the source.

The latest 15th Open-ended Working Group (OEWG-15) of the Basel Convention in Geneva instigated debates regarding plastic waste management. Without a finalized legally binding Plastics Treaty, a Norwegian proposal was reviewed by parties to fill up the gaps for recyclable plastics management rules, preparing for the upcoming 18th Conference of the Parties (COP 18).

3.3 Critical analysis of laws and regulations in Bangladesh

Despite progress in chemical and plastic governance, Bangladesh currently has no specific legal or regulatory provisions addressing intentionally added microplastics in toothpaste or other oral care products. While restrictions exist on the use of plastic microbeads in facewash products, no comparable regulatory measures have been introduced for toothpaste. Existing laws and product standards primarily focus on product quality, safety, and general labelling, but do not require microplastic testing, disclosure of synthetic polymer ingredients, or restrictions on intentionally added microplastics in toothpaste.

Furthermore, Bangladesh lacks standardized testing protocols, routine regulatory monitoring, and mandatory screening for microplastics in oral care products. Although advanced analytical techniques such as FTIR and Raman spectroscopy are available in selected laboratories, they have not yet been integrated into regulatory compliance and surveillance systems. Addressing these regulatory and technical gaps will be essential to strengthen consumer protection, support evidence-based policymaking, and facilitate the transition toward microplastic-free oral care products.

[19] Andrea Willige, "INC-5.2: The Global Plastics Treaty Talks – Here's What Just Happened," *World Economic Forum*, August 15, 2025,
[20] Tallash Kantai, "INC-5.3: Where the Global Plastics Treaty Talks Stand, and Why This Meeting Matters," *International Institute for Sustainable Development (IISD)*, February 4, 2026, https://www.iisd.org/articles/explainer/inc5.3-global-plastics-treaty-talks-why-meeting-matters.
[21] "Intergovernmental Negotiating Committee on Plastic Pollution," *UNEP - UN Environment Programme*, n.d., https://www.unep.org/inc-plastic-pollution.

3.4 Comparison with global practices

Table 2. Global Policies Prohibiting Microplastic Use in Toothpaste

Country	Regulations Restricting Microplastic Use in Toothpaste
United States	The amended Federal Food, Drug and Cosmetic Act (FFDCA), Microbead-Free Waters Act 2015, banned the manufacture and sale of non-prescription drugs (over-the-counter) and rinse-off cosmetics with intentionally added plastic microbeads, such as toothpastes. Its strict implementation was phased from 2017 onward.[22]
European Union	The EU adopted Commission Regulation (EU) 2023/2055 under REACH, restricting intentionally added microplastics in products. The regulation mandates labelling, monitoring, and timelines for phase-out, covering cosmetics and other consumer goods.[23]
Argentina	Law 27,602 of 2020 banned the production, import, and sale of all oral hygiene items for dental use that contain intentionally added plastic microbeads.[24]
South Korea	The addition of plastic microbeads in toothpaste is banned under the **Cosmetics Act** (화장품법) and its revised **Regulation on Safety Standards, etc. for Cosmetics**.[25]
Taiwan	Taiwan banned manufacture and import of products, including toothpaste, containing microbeads via the amendment **"Restrictions on the Manufacture, Import, and Sale of Personal Care and Cosmetics Products Containing Plastic Microbeads"** under the **Waste Disposal Act** in 2018.[26]

[22] U.S. Food and Drug Administration, *Microbead-Free Waters Act of 2015: Guidance and Implementation* (Washington, DC: U.S. Food and Drug Administration, 2015).
[23] European Commission, *Commission Regulation (EU) 2023/2055 of 25 September 2023 Amending Annex XVII to Regulation (EC) No. 1907/2006 of the European Parliament and of the Council Concerning the Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH) as Regards Synthetic Polymer Microparticles*, *Official Journal of the European Union* L238 (September 27, 2023): 67–88.
[24] "BOLETIN OFICIAL REPUBLICA ARGENTINA - PRODUCTOS COSMÉTICOS Y PRODUCTOS DE HIGIENE ORAL DE USO ODONTOLÓGICO - Ley 27602," n.d., https://www.boletinoficial.gob.ar/detalleAviso/primera/239237/20201229
[25] Banned Substance Found in 87% of 2080 Toothpaste Products Sampled," January 20, 2026, https://world.kbs.co.kr/service/news_view.htm?lang=e&Seq_Code=198970
[26] Admgaia and Admgaia, "Taiwan Soon to Be Plastic Free | GAIA," *GAIA* | (blog), November 13, 2021, https://www.no-burn.org/taiwan-soon-to-be-plastic-free/.

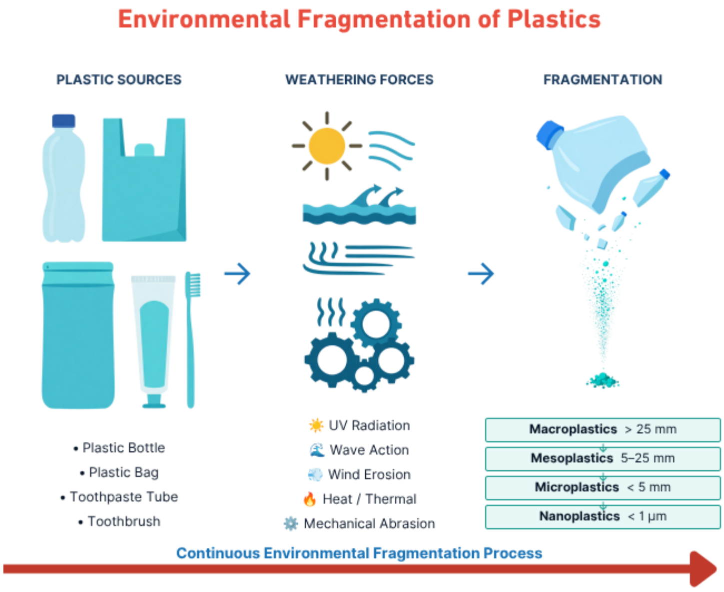
4. Environmental and Public Health Implications of Microplastics

Microplastics are a growing environmental and public health concern due to their persistence, widespread distribution, ability to accumulate in ecosystems, and potential interactions with biological systems and chemical contaminants. Their small size allows them to move through aquatic, terrestrial, and atmospheric environments, making them difficult to remove once released.

4.1 Environmental Implications of Microplastics

1. Environmental Persistence

Microplastics persist in the environment largely because conventional plastics lack the chemical structure needed for microbial or enzymatic breakdown; instead of biodegrading, they undergo a slow physical and chemical breakdown process driven by sunlight (UV-induced photo-oxidation), heat, mechanical abrasion from waves and wind, and oxidative reactions with ambient pollutants such as ozone and nitrogen dioxide.[27]



This persistence is precisely why plastic has become, by weight, the dominant category of marine debris. A widely cited figure places plastic at approximately 85% of total marine litter, and because fragmentation is a continuous cascade, macroplastics into mesoplastics, into microplastics, and eventually into nanoplastics, particles already in the environment do not disappear so much as multiply and shrink in size over time, expanding their bioavailability to progressively smaller organisms.[28]

2. Wastewater Pathway and Incomplete Removal

Wastewater treatment plants (WWTPs) are simultaneously one of the most effective known interventions against microplastic pollution and one of its most persistent structural sources. A systematic review synthesizing over a decade of published data found that primary treatment alone removes a highly variable 16.5% to 98.4% of microplastics, secondary treatment achieves an overall removal efficiency of 78.1% to 100%, with individual stages ranging from as little as 7% for standard activated sludge to as high as 99.9% for membrane bioreactor systems and tertiary treatment removes an overall 87.3% to over 99.9%.[29]

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[27]Andrady, A.L. (2011). Microplastics in the marine environment. Marine Pollution Bulletin, 62(8), 1596-1605; and Andrady, A.L. (2015). Persistence of plastic litter in the oceans, in Marine Anthropogenic Litter, Springer, Cham, pp. 57-72.
[28]Okoffo, E.D. et al. and related reviews. Microplastics in marine and aquatic habitats: sources, impact, and sustainable remediation approaches. PMC, NCBI, PMC8923096.
[29]Efficiency of Wastewater Treatment Plants (WWTPs) for Microplastic Removal: A Systematic Review. PMC, NCBI, PMC7663475.

Global Pathway of Microplastics from Toothpaste to the Environment and Human Exposure

1. Toothpaste Containing Primary Microplastics
Particles: PE, PP, PMMA, EVA, Nylon, PET

PE · PP · PMMA · EVA · Nylon · PET

2. Daily Tooth Brushing
Microplastics released into sink during brushing

3. Household Wastewater Drain
Sink drain connected to underground sewer pipes

SPLIT

Wastewater Treatment Plant (WWTP)

Partial removal of microplastics.
Some trapped in sludge,
others escape to waterways.

Untreated Wastewater Discharge

Wastewater flows directly
into rivers without treatment.

MERGE

4. Rivers, Lakes, Estuaries and Oceans
Microscopic plastic particles accumulate in aquatic environments

5. Aquatic Organisms
Fish, shellfish, plankton, and aquatic plants ingesting microplastics

Fish · Shellfish · Plankton · Plants

6. Food Chain Transfer
Fish → Seafood → Human Plate

Bioaccumulation through trophic levels

7. Human Exposure
Multiple exposure routes identified:

Drinking Water · Seafood · Salt · Air · Toothpaste

Key Finding: Daily use of toothpaste containing primary microplastics contributes to continuous environmental release through wastewater systems, eventually reaching aquatic ecosystems and the human food chain.

treatment, with removal efficiency varying by particle size, polymer type, and shape: particles larger than 500 micrometers were removed at rates exceeding 90% after tertiary treatment, fragment-shaped particles were removed more effectively than bead-shaped ones, and treatment level, rather than wastewater origin, plant size, or geographic location was found to be the dominant factor determining overall performance.[30]

Even at these high removal percentages, WWTPs remain a meaningful source of environmental release because of the sheer daily volume of wastewater processed: a treatment level that removes 99% of particles from millions of liters per day can still discharge a substantial absolute number of particles annually. One study modeling total daily microplastic load found values ranging from roughly 1.84 million particles per day at a well-performing tertiary plant to over 77 million particles per day at a lower-performing plant using conventional activated sludge, both from real-world facilities.[31]

Particles that are captured rather than discharged do not vanish, they concentrate in sewage sludge, with reported figures indicating that up to 99% of the microplastics entering a plant in wastewater ultimately end up in the treated sludge fraction, and fibrous microplastics in particular were found to be especially concentrated in dewatered sludge. Because sewage sludge (biosolids) is frequently applied to agricultural land as fertilizer or soil conditioner in many countries, this creates a secondary transfer pathway that effectively converts a captured aquatic pollutant into a terrestrial and agricultural one.[32]

3. Widespread Aquatic Contamination

Microplastics have now been documented across essentially every aquatic compartment studied. rivers, lakes, estuaries, coastal waters, open ocean surface waters, deep-sea sediments, and even polar ice. One comprehensive review estimates that approximately 5.25 trillion plastic particles are currently floating in the world's oceans, and that degrading plastic in aquatic systems releases as much as 23,600 metric tonnes of dissolved organic carbon annually, a byproduct that itself disrupts microbial carbon cycling in affected waters.[33]

Once in aquatic systems, particle fate depends heavily on density and biofouling: buoyant polymers such as polyethylene and polypropylene tend to remain in the water column or at the surface initially, but the growth of microbial biofilms on particle surfaces progressively increases their effective density, causing many particles that started out floating to eventually sink. Transport is further governed by ocean currents, river discharge, tidal action, and storm-driven runoff, which together can move particles across ocean basins and deposit them thousands of kilometers from their point of origin.[34]

4. Sediment and Benthic Ecosystems

Sediments function as a long-term reservoir for microplastics rather than a terminal sink. Because denser or biofouled particles settle out of the water column into riverbeds, estuarine mud, and seafloor sediment, benthic organisms — worms, mollusks, crustacean larvae, and

[30] Removal of microplastics in wastewater treatment plants: insights from a literature meta-analysis. (2025). ScienceDirect, Journal of Water Process Engineering.

[31] Particle balance and return loops for microplastics in a tertiary-level wastewater treatment plant. (2021). Water Science & Technology, IWA Publishing, 84(1), 89.

[32] Zhang, Y. & Chen, Y. (2020), as summarized in: Particle balance and return loops for microplastics in a tertiary-level wastewater treatment plant. Water Science & Technology, IWA Publishing.

[33] Microplastics in aquatic systems: A comprehensive review of its distribution, environmental interactions, and health risks. PMC, NCBI, PMC11717821.

[34] Microplastic pollution in the marine environment: Sources, impacts, and degradation. PMC, NCBI, PMC12186783.

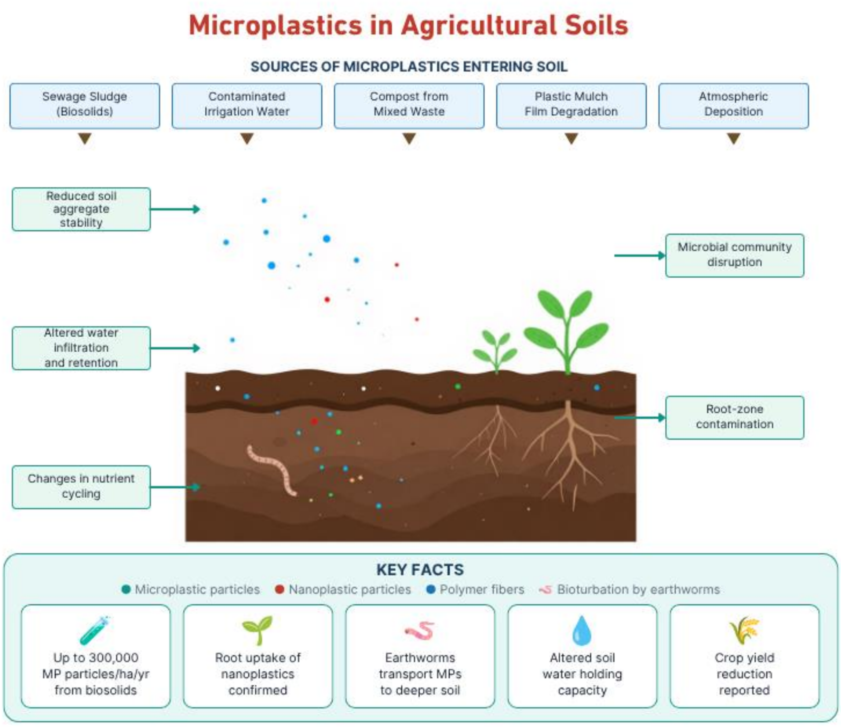
demersal (bottom-dwelling) fish, experience chronic, direct contact with accumulated particles in a way that pelagic (open-water) species generally do not.[35]

This sediment reservoir is not permanently stable. Disturbance events- flooding, storms, dredging activity, and strong tidal or river turbulence can resuspend previously buried microplastics back into the water column, effectively re-releasing pollution that had appeared to be sequestered. This resuspension dynamic complicates efforts to treat sediment deposition as a permanent removal mechanism and means benthic ecosystems can face repeated, pulsed re-exposure over long timescales.[36]

5. Soil and Agricultural Impacts

Microplastics reach agricultural soils through multiple converging pathways: land application of sewage sludge/biosolids, irrigation with contaminated water, compost derived from mixed waste streams, degradation of plastic mulch films used widely in modern farming, and atmospheric deposition of airborne fibers settling onto fields.[37]

Once present in soil, microplastics can measurably alter its physical structure: reviews report reduced soil aggregate stability, altered water infiltration and retention rates, and changed nutrient-retention capacity, effects that intensify in intensively managed croplands with heavy plastic mulch use. Because polyethylene is hydrophobic, its presence in soil specifically affects water movement and retention patterns, while other common agricultural polymers such as PVC can leach plasticizer additives that interfere separately with microbial nitrogen cycling.[38]



Effects on the soil microbiome are similarly well documented, though directionally complex. Meta-analyses report that microplastic-contaminated soils generally show distinct and often lower microbial diversity than uncontaminated soils, with the specific response depending on soil texture — coarse-textured soils showed enhanced fungal richness after microplastic addition in some studies, while medium-textured soils showed declines in both bacterial and fungal diversity. Some studies also report a shift in the relative abundance of functional

[35] Zhang, Y. & Chen, Y. (2020), as summarized in: Particle balance and return loops for microplastics in a tertiary-level wastewater treatment plant. Water Science & Technology, IWA Publishing.
[36] Microplastics in aquatic systems: A comprehensive review of its distribution, environmental interactions, and health risks. PMC, NCBI, PMC11717821.
[37] Microplastics in agricultural soils: Impacts on soil microbial communities, nutrient cycling, earthworm health, and soil ecosystem functions. (2026). ScienceDirect.
[38] Microplastic effects on soil nitrogen storage, nitrogen emissions, and ammonia volatilization in relation to soil health and crop productivity: mechanism and future consideration. (2025). Frontiers in Plant Science; PMC, NCBI, PMC12515873.

bacterial groups: increases in nitrogen-fixing and phosphorus-solubilizing bacteria alongside decreases in nitrifying and ammonia-oxidizing bacteria, with knock-on effects for bioavailable nitrogen and phosphorus levels and, in some cases, elevated nitrous oxide emissions — a greenhouse gas.[39]

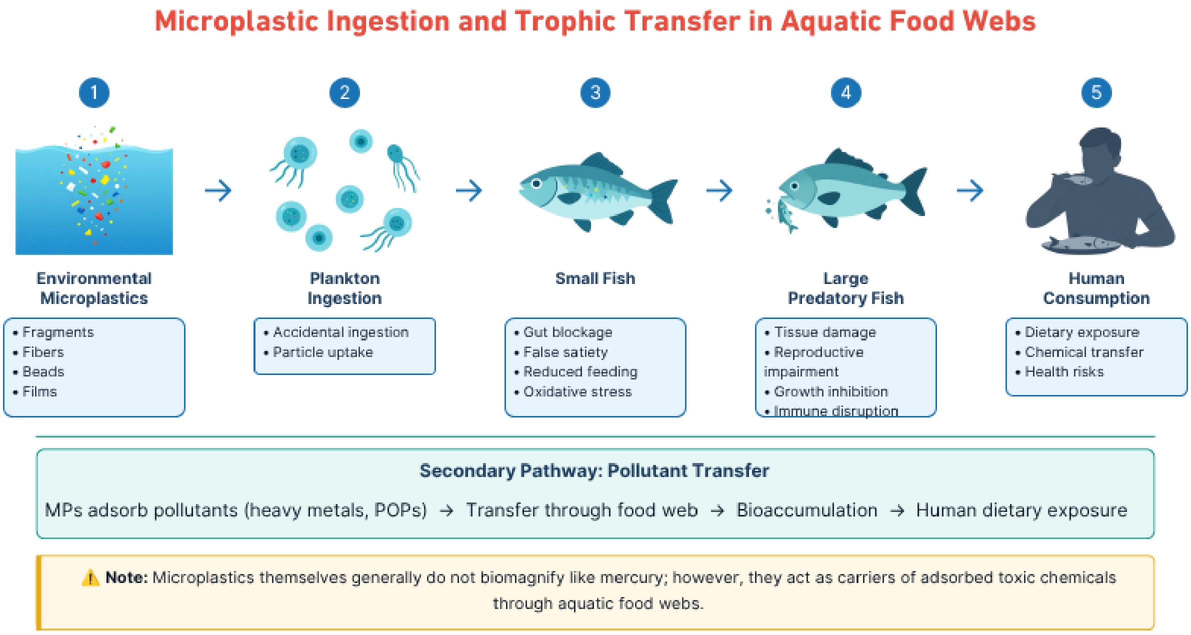
Soil fauna are directly affected as well. Earthworms, long assumed to help process organic contaminants, have instead been characterized in recent reviews as vectors of microplastic redistribution and fragmentation rather than agents of detoxification — their feeding and burrowing activity breaks larger microplastics into smaller, more bioavailable and mobile particles, transports them to deeper soil layers and plant root zones, and increases the particles' surface area available for further contaminant adsorption. Because these physical and microbial effects feed back into nutrient cycling and root development, researchers note that long-term impacts on crop productivity and food security remain an active and still-developing area of investigation rather than a settled conclusion.[40]

6. Ingestion by Aquatic Organisms

Microplastics are readily ingested across aquatic food webs; one review notes their detection in over 150 fish species, and a separate estimate places the number at 728 fish species worldwide, largely because their small size and irregular shape can resemble natural prey items such as zooplankton, and because particles are frequently ingested incidentally alongside actual food or attached to it via biofilm.

Physical Effects

Once ingested, larger microplastic fragments can physically block the digestive tract, and controlled feeding studies confirm this produces "false satiety" or "phantom satiety"- a sensation of fullness despite inadequate actual nutrient intake, that in turn suppresses normal feeding behavior. In more severe cases, documented outcomes include ulcerative intestinal lesions, gut wall perforation, and stomach rupture, any of which can be fatal, with early life



[39]Effects of microplastics on soil microorganisms and microbial functions in nutrients and carbon cycling - A review. (2024). PubMed, PMID: 38438042.

[40] Microplastics in agricultural soils: Impacts on soil microbial communities, nutrient cycling, earthworm health, and soil ecosystem functions. (2026). ScienceDirect.

stages (larvae and juveniles) shown to be substantially more vulnerable to these physical harms than mature adult fish.[41]

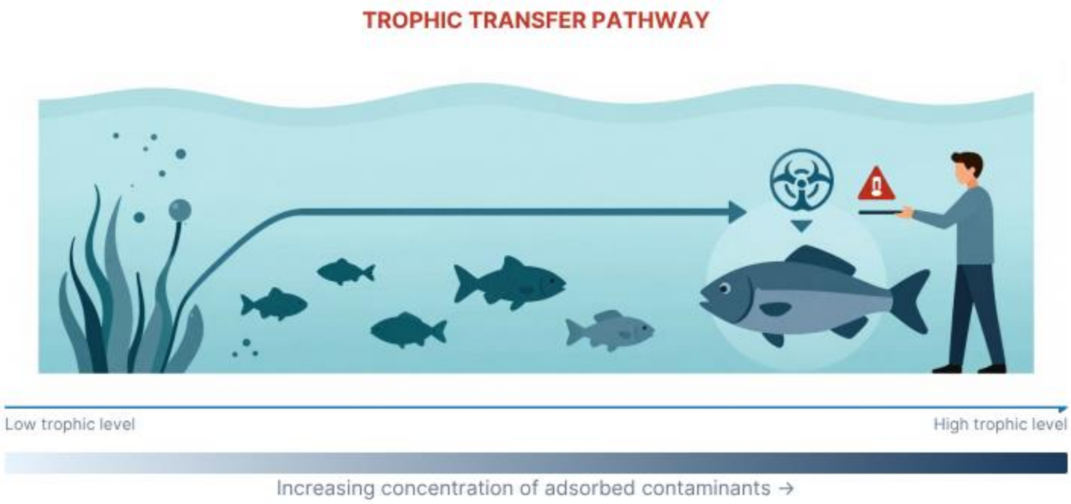
Physiological And Reproductive Effects

Beyond direct physical damage, ingested microplastics are associated with a broad suite of physiological effects documented across laboratory studies: oxidative stress from disrupted antioxidant defenses, immune system alteration, neurotoxicity via inhibited acetylcholinesterase activity, hepatic and gut tissue damage with disrupted intestinal barrier function, and altered digestive enzyme activity that impairs growth performance. A large-scale analysis pooling 3,757 biological endpoints from 85 laboratory studies concluded that microplastic exposure significantly inhibits fish growth, survival, and reproductive ability, and increases oxidative damage markers, while finding no significant effect on gut microbiota diversity specifically, a useful reminder that not every proposed mechanism is equally well supported across the literature.[42]

Reproductive impacts are mechanistically tied to disruption of the hypothalamic-pituitary-gonadal (HPG) axis, with documented effects including interference with steroidogenesis (hormone production) and apoptosis (programmed cell death) in gonadal tissue, ultimately manifesting as reduced reproductive performance and impaired offspring development.[43]

Microplastics move through food webs when a contaminated organism is consumed by a predator further up the chain, plankton eaten by small fish, small fish eaten by larger fish, and larger fish eventually consumed by humans, with the pathway equally applicable on land, where earthworms that ingest soil-borne microplastics can transfer them to birds or mammals that feed on them.[44][45]

It is worth being precise about terminology here: unlike classical biomagnifying chemicals such as mercury, microplastic particles themselves are generally understood not to biomagnify in the traditional sense, since they are physical particles rather than chemicals that concentrate in fatty tissue. What can transfer and concentrate through the food chain, however, are the



[41] An end to the controversy over the microscopic detection and effects of pristine microplastics in fish organs. (2020). Scientific Reports, DOI: 10.1038/s41598-020-69062-3.
[42] Microplastics bioaccumulation in fish: Its potential toxic effects on hematology, immune response, neurotoxicity, oxidative stress, growth, and reproductive dysfunction. PMC, NCBI, PMC11720882.
[43] Impacts of Microplastics on the Early Life Stages of Fish: Sources, Mechanisms, Ecological Consequences, and Mitigation Strategies. PMC, NCBI, PMC12845772.
[44] MICROPLASTIC: FROM marine pollution to the human food chain. (2025). ScienceDirect.
[45] Microplastics and nanoplastics in the terrestrial food chain: Uptake, translocation, trophic transfer, ecotoxicology, and human health risk. (2023). ScienceDirect.

chemical contaminants- heavy metals and persistent organic pollutants that become adsorbed onto microplastic surfaces, meaning the particles function more as a delivery vector for trophic transfer of chemical toxicity than as a directly biomagnifying substance in their own right.[46][47]

This pathway carries particular relevance for regions such as Bangladesh, where fish and other aquatic foods represent a major dietary staple and where freshwater and coastal ecosystems are closely tied to both food security and livelihoods. Fish caught in the Bay of Bengal a region facing significant plastic input from dense coastal population, industrialization, urban expansion, and active commercial fishing, have been documented with measurable microplastic contamination, which was used as the basis for a formal consumer risk assessment given the region's heavy reliance on marine fish as a protein source.[48]

7. Chemical Carrier and Ecotoxicological Risk

Microplastics rarely act as chemically inert particles alone. Manufacturing additives plasticizers, stabilizers, flame retardants, pigments, fillers, and unreacted residual monomers are incorporated into plastic during production and are not chemically bound to the polymer matrix, meaning they can leach out gradually once the particle is in the environment or inside an organism.[49]

Separately, microplastics' hydrophobic, high-surface-area structure allows them to actively adsorb and concentrate environmental contaminants already present in the surrounding water or soil, including persistent organic pollutants (POPs), heavy metals, pesticides, and pharmaceuticals, at levels that can significantly exceed the ambient concentration in the surrounding environment. The formation of biofilms on particle surfaces — sometimes called the "plastisphere" — further increases this adsorption capacity by adding functional chemical groups to the particle surface and can additionally harbor pathogenic microorganisms and antibiotic-resistance genes, compounding the ecotoxicological risk beyond the plastic and its native additives alone.

Overall toxicity is therefore not a fixed property of "microplastics" as a single category but a function of several interacting variables: particle size, shape, polymer type, surface area, degree of environmental weathering, the specific additive package used in manufacturing, and the particular suite of pollutants a given particle has adsorbed from its local environment — meaning risk can vary substantially between two microplastic particles of the same polymer type collected from different locations.[50]

8. Bangladesh-Specific Environmental Relevance

Bangladesh's exposure to this pollution pathway has intensified rapidly alongside its economic development: annual per-capita plastic consumption in urban areas rose from approximately 3 kg in 2005 to 9 kg by 2020. Of the total plastic consumed nationally that year, only 31% was captured through recycling, leaving a substantial majority to enter waste streams with limited formal management infrastructure.[51]

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[46]Marine microplastics: Environmental fate, trophic transfer and implications for ecosystem and human health. (2026). ScienceDirect.

[47]Trophic transfer, bioaccumulation and translocation of microplastics in an international listed wetland on the Montreux record. (2024). ScienceDirect.

[48]Microplastic contamination in some popular seafood fish species from the northern Bay of Bengal and possible consumer risk assessment. (2024). ScienceDirect.

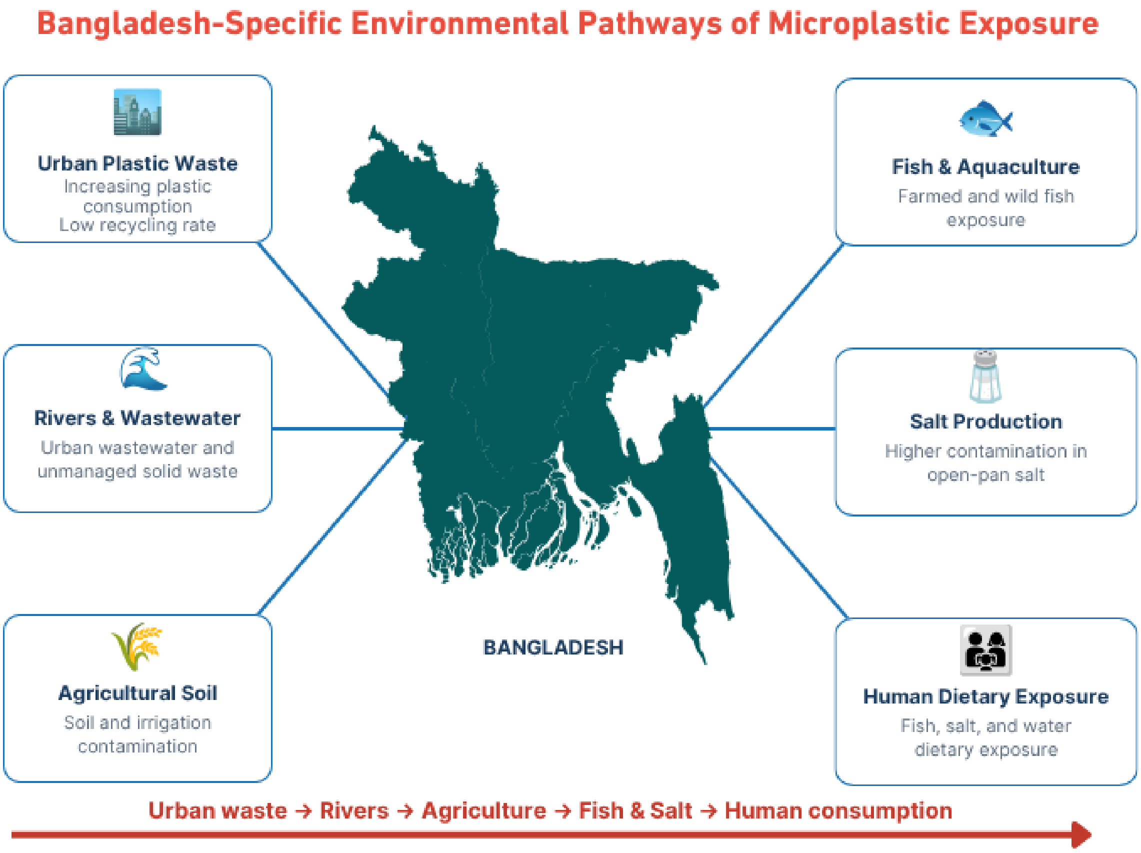
[49]Microplastics supply contaminants in food chain: non-negligible threat to health safety. (2024). Environmental Geochemistry and Health, Springer Nature.

[51]Understanding the characteristics, sources, potential impacts, and removal efficiencies of microplastics in wastewater treatment plants. (2025). ScienceDirect (reports 977,000-tonne 2020 Bangladesh plastic-consumption figure as cited in national reviews); and Understanding the Occurrence and Fate of Atmospheric Microplastics and Their Potential Risks to Human Health: Protocol for a Cross-Sectional Analysis. PMC, NCBI, PMC11645502.

A national-scale systematic review synthesizing 50 peer-reviewed studies published through December 2024 found widespread microplastic contamination across water, sediment, biota, fish feed, agricultural fertilizer, and table salt, with polyethylene, polypropylene, and polystyrene identified as the most frequently detected polymers and textile-derived fibers flagged as a dominant contributing source. The same review reported that tea bags sold in Bangladesh contained particularly high microplastic levels relative to other tested products, and it linked documented health implications — oxidative stress and immune system effects in aquatic organisms, and potential human dietary exposure via fish and salt consumption — directly to these contamination findings.[52]

Salt-specific testing in the Cox's Bazar and Maheshkhali region of the Bay of Bengal found that open-pan salt, a traditional local production method, carried a notably higher microplastic burden than commercially packaged salt, pointing to production and processing method as a meaningful determinant of dietary exposure risk within the same national food supply.[53]

Separately, research on fish feed used in Bangladeshi aquaculture has found microplastic contamination in feed products themselves, representing an additional, upstream exposure pathway for farmed fish that is distinct from contamination picked up directly from the surrounding aquatic environment — relevant given that a large share of Bangladesh's fish supply for human consumption is farmed rather than wild-caught.[54]



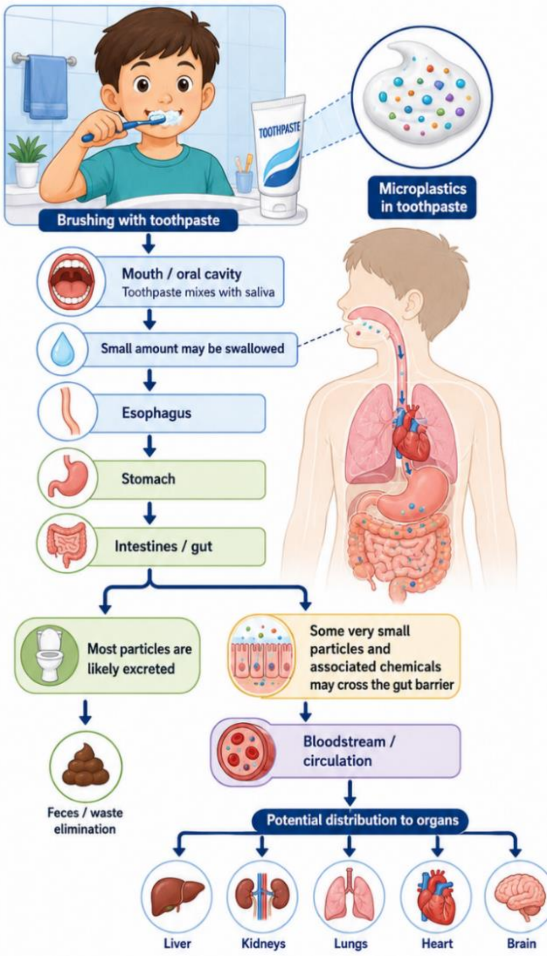
[52]Microplastics contamination in freshwater and marine ecosystems, its impacts, and sustainable mitigation pathways in Bangladesh: a systematic review. (2025). Discover Toxicology, Springer Nature.
[53]An investigation on the prevalence of microplastic in commercial and open pan salts obtained from Cox's Bazar and Maheshkhali region of Bay of Bengal (Bangladesh). (2023). Food Science & Nutrition, Wiley.
[54]Microplastics contamination in fish feeds: Characterization and potential exposure risk assessment for cultivated fish of Bangladesh. (2023). ScienceDirect.

Taken together, this body of national research indicates that Bangladesh faces a compounding set of environmental exposure pathways — from urban wastewater and inadequately managed solid waste, through agricultural soil and irrigation water, into the aquatic food supply via fish, salt, and fish feed — that collectively mirror, and in several respects (such as low recycling capture and heavy dietary dependence on aquatic protein) may intensify, the broader global environmental patterns described in Sections 1 through 8.[55]

4.2. Health Impacts of Microplastics

Humans may be exposed to microplastics through ingestion, inhalation of airborne particles, and, to a lesser extent, dermal contact. Microplastics have been detected in various environmental media, including drinking water, seafood, food products, air, and consumer products. The potential for human exposure depends on particle characteristics such as size, polymer type, concentration, surface properties, and exposure duration. Recent studies have also reported the presence of microplastics in human biological samples, indicating that some particles may enter and circulate within the human body[56].

Consumer products, including toothpaste, represent a potential direct and preventable exposure pathway. Studies have identified microplastics in commercially available toothpaste products, including fragments and fibres composed of different polymers. Due to the frequent use of toothpaste and its direct contact with the oral cavity, the presence of microplastics in such products raises concerns regarding repeated exposure and their contribution to overall human microplastic exposure[57]. While direct clinical evidence linking oral-care-derived microplastics to specific human health outcomes remains limited, their potential contribution to overall microplastic exposure and biological effects warrants further investigation.



Scientific evidence on the human health effects of microplastics is still developing; however, recent studies suggest that microplastic exposure may be associated with biological responses, including inflammation, oxidative stress, cellular damage, immune system activation, and potential endocrine-related effects. These effects may result from particle-cell interactions, the release of plastic-

[55]Microplastic pollution scenario and its effects on public health and ecosystem: a Bangladesh perspective. (2024). International Journal of Environmental Science and Technology, Springer Nature.
[56] Ririe, A. K., Fatema, N., Dina, T. J., Devi Kuchipudi, J., Tamanna, P., Libriansyah, L., Akter, T., & Kaderi, N. (2025). Impact of Microplastic Exposure on Human Health: A Systematic Review of Mechanisms, Biomarkers, and Clinical Outcomes. Cureus, 17(12), e100295. https://doi.org/10.7759/cureus.100295
[57] Madhumitha, C. T., Karmegam, N., Biruntha, M., Arun, A., Al Kheraif, A. A., Kim, W., & Kumar, P. (2022). Extraction, identification, and environmental risk assessment of microplastics in commercial toothpaste. Chemosphere, 296, 133976. https://doi.org/10.1016/j.chemosphere.2022.133976

associated chemicals, or the ability of microplastics to carry other environmental contaminants[58].

Human biomonitoring studies have detected plastic particles in human blood, indicating that some plastic particles can enter the human body and become biologically available. However, the long-term health implications of microplastic exposure and their potential contribution to specific health outcomes remain uncertain and require further investigation[59].

Respiratory and Lung Effects

Inhalation is, alongside ingestion, one of the two dominant human exposure routes, and it's a growing research focus in its own right. Microplastics have been directly identified in human lung tissue and in the sputum of patients with respiratory disease, confirming that airborne particles are inhaled deep enough to lodge in the lungs rather than being fully cleared by the upper airway.[60]

At the cellular level, microplastics interacting with lung epithelial cells trigger reactive oxygen species production, deplete the body's antioxidant defenses, and disrupt mitochondrial function- a combination that damages cells, impairs tissue repair, and can push cells into premature senescence. These same pathways interfere with autophagy and promote a process called epithelial-mesenchymal transition, which is linked to tissue scarring.[61]

A 2025 review synthesizing this evidence base concludes that microplastic exposure is increasingly linked, in both epidemiological and experimental studies, to lung cancer, asthma, chronic obstructive pulmonary disease, and pulmonary fibrosis — though it stresses that the precise mechanisms and dose-response relationships in humans are still poorly defined. Notably, indoor air concentrations of airborne microplastic fibers can run several times higher than outdoor levels, largely from synthetic textiles and laundering, meaning most people's greatest inhalation exposure happens at home rather than outdoors.[62]

A systematic review focused specifically on occupational and clinical evidence concludes that inhaled microplastics and their chemical additives are capable of promoting pro-inflammatory and pro-carcinogenic effects, with the strength of evidence varying by particle size, polymer type, and surface charge, and notes that most of the underlying data still comes from in vitro work rather than population cohort studies.[63]

Cardiovascular Effects

The most consequential human evidence to date on microplastics and any organ system may be cardiovascular. A landmark 2024 study published in the New England Journal of Medicine analyzed carotid artery plaque removed during surgery from over 300 patients and found that those whose plaque contained detectable microplastics and nanoplastics had roughly 4.5

[58] Madhumitha, C. T., Karmegam, N., Biruntha, M., Arun, A., Al Kheraif, A. A., Kim, W., & Kumar, P. (2022). Extraction, identification, and environmental risk assessment of microplastics in commercial toothpaste. Chemosphere, 296, 133976. https://doi.org/10.1016/j.chemosphere.2022.133976
[59] Leslie, H. A., van Velzen, M. J. M., Brandsma, S. H., et al. (2022). “Discovery and quantification of plastic particle pollution in human blood.” Environment International, 163, 107199.
[60] Microplastics inhalation and their effects on human health: a systematic review. PMC, NCBI, PMC9835049.
[61] Inhaled microplastics and lung health: Immunopathological effects and disease implications. (2025). ScienceDirect.
[62] Microplastics as environmental modifiers of lung disease. (2025). EMBO Molecular Medicine, Springer Nature, PMC12905266.
[63] Microplastic and plastic pollution: impact on respiratory disease and health. PubMed, PMID: 39009408.

times the risk of heart attack, stroke, or death over the following three years compared to patients whose plaque was plastic-free.[64]

Subsequent studies have extended this finding: microplastics have since been detected not just in carotid plaque but in coronary arteries and in aortic tissue, with concentrations consistently higher in arteries that already show atherosclerotic plaque than in plaque-free vessels. One study also found a positive correlation between blood microplastic concentration and the complexity of coronary artery lesions, alongside elevated inflammatory markers (IL-6, IL-12p70) in patients with acute coronary syndrome.[65]

Mechanistic reviews propose that microplastics contribute to cardiovascular risk through oxidative stress, cell death, and fibrotic tissue scarring in heart tissue, plus microvascular effects including hemolysis (red blood cell breakdown), abnormal clotting, and endothelial dysfunction (impaired blood vessel lining function) all recognized contributors to atherosclerosis and its complications.[66]

Neurological and Brain Effects

Perhaps the most striking recent finding is that microplastics accumulate in the human brain, and apparently more than in other major organs. A 2025 study in Nature Medicine examined brain, liver, and kidney tissue from autopsies and found that brain samples contained substantially higher concentrations of micro- and nanoplastics than liver or kidney samples from the same period, with polyethylene as the dominant polymer. The same study found that total plastic mass in brain tissue had risen by roughly 50% between 2016 and 2024, and that brains from people diagnosed with dementia carried markedly higher plastic concentrations than brains from people without dementia — though the authors are explicit that this does not establish that microplastics cause dementia.[67]

A broader review of the mechanistic literature describes microplastics in brain tissue triggering oxidative stress, chronic neuroinflammation involving microglia and astrocytes (the brain's immune and support cells), mitochondrial energy deficits, disrupted neurotransmitter systems, and direct neuronal damage. Some nanoplastic studies have also shown that particles can promote the aggregation of proteins implicated in neurodegenerative disease, such as alpha-synuclein.[68]

One 2024 study using high-resolution imaging in mice found that circulating microplastics were engulfed by immune cells that then became lodged in brain capillaries, forming blockages that reduced blood flow and produced measurable neurobehavioral abnormalities — a proposed physical mechanism (rather than a purely chemical one) by which circulating plastic particles could affect brain function.[69]

[64]Marfella, R. et al. (2024). Microplastics and Nanoplastics in Atheromas and Cardiovascular Events. New England Journal of Medicine, 390, 900–910. DOI: 10.1056/NEJMoa2309822.

[65]Micro-nanoplastic induced cardiovascular disease and dysfunction: a scoping review. (2025). Journal of Exposure Science & Environmental Epidemiology, Nature.

[66]Microplastics and nanoplastics: emerging threats to cardiovascular health – a comprehensive review. PMC, NCBI, PMC11918686.

[67]Nihart, A.J. et al. (2025). Bioaccumulation of microplastics in decedent human brain, liver, and kidney tissue, and comparison with 2016 samples. Nature Medicine.

[68]Overall effects of microplastics on brain. PMC, NCBI, PMC12675269.

[69]Microplastics in the bloodstream can induce cerebral thrombosis by causing cell obstruction and lead to neurobehavioral abnormalities. (2024). Science Advances. DOI: 10.1126/sciadv.adr8243.

Reproductive and Fertility Effects

Microplastics have now been detected directly in human reproductive tissue and fluids, including testicular tissue, semen, follicular fluid, and placenta.

A 2025 review synthesizing the human evidence base notes that animal studies have consistently demonstrated that microplastic exposure can impair reproductive function through hormonal disruption, oxidative damage, and histological changes in reproductive organs of both sexes but that translating these findings into confirmed human reproductive health effects remains underexplored, with human research still fragmented across small, largely observational studies.[70]

In-vitro exposure of human sperm to polystyrene microplastics has been shown to reduce sperm vitality and motility in a time-dependent manner and to cause sperm agglutination (clumping), even though overall sperm concentration and morphology were unaffected, pointing to functional rather than purely structural impairment.[71]

A multi-site Chinese study linking urinary microplastic exposure to semen quality found that certain polymer types notably PTFE, associated with non-stick cookware coatings — were significantly associated with sperm dysfunction, and proposed urine testing as a potential non-invasive marker of reproductive microplastic exposure going forward.[72]

Cancer and Genotoxicity

The cancer-risk evidence for microplastics is the newest and least mature of the areas covered here, but it is developing quickly, particularly around colorectal cancer. A 2025 study identified microplastics directly within tumor tissue and adjacent peritumoral tissue in colorectal cancer patients, finding a greater variety and distribution of particles in tumor tissue than in nearby non-cancerous tissue, and noting that a protein involved in cellular particle uptake (clathrin) was highly expressed in the cancer specimens studied.[73]

A systematic review of the clinical literature on microplastics and colorectal cancer describes several plausible contributing mechanisms: disruption of the protective colonic mucus layer, microplastics acting as carriers for other toxic and carcinogenic chemicals, and microplastic-driven changes to the gut microbiota that may increase colon cells' exposure to harmful compounds with some researchers proposing a link to the rising incidence of early-onset colorectal cancer in younger adults.[74]

A broader rapid systematic review assessing multiple organ systems rated the overall body of evidence for digestive, reproductive, and respiratory effects of microplastic exposure as "moderate" quality, concluding these outcomes are "suspected" to be adversely affected by exposure, with a specifically flagged suggested link to colon and lung cancer while cautioning

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[70]Microplastics and human fertility: A comprehensive review of their presence in human samples and reproductive implication. (2025). ScienceDirect.

[71]Impact of Polystyrene Microplastics on Human Sperm Functionality: An In Vitro Study of Cytotoxicity, Genotoxicity and Fertility-Related Genes Expression. PMC, NCBI, PMC12298576.

[72]Association of mixed exposure to microplastics with sperm dysfunction: a multi-site study in China. PMC, NCBI, PMC11663775.

[73]Identification and analysis of microplastics in peritumoral and tumor tissues of colorectal cancer. (2025). Scientific Reports, Nature.

[74]The clinical relevance of microplastic exposure on colorectal cancer: A systematic review. (2025). ScienceDirect.

that most existing reviews on this topic have been non-systematic and that rigorous, standardized human studies are still needed across the board.[75]

Across all five systems above, a consistent pattern holds: particle detection in human tissue is now well established, mechanistic and animal evidence for harm is often strong, and human association studies are emerging — but direct, causally proven human health outcomes remain the exception rather than the rule, and researchers across nearly every cited study call for larger, standardized, longitudinal human research to close that gap.

Gastrointestinal and Ingestion-Related Effects

The gastrointestinal tract is the first and most direct site of contact for swallowed toothpaste and other ingested microplastics, and it's the most heavily studied organ system in this literature. Simulated human digestion experiments using polyethylene terephthalate (PET) microplastics found that particles altered the composition of colonic microbial communities and underwent partial structural breakdown during gut passage.[76]

A systematic review of twelve human-relevant studies on microplastics and the gut microbiome reported a consistent pattern: a shift away from beneficial bacterial genera (like Lactobacillus and Bifidobacterium) toward pro-inflammatory and potentially pathogenic species, along with impaired short-chain fatty acid production and disrupted immune signaling in the gut.[77]

In-vitro exposure of human intestinal cells (HT-29 line) to microplastics in the low-micron range produced measurable cytotoxicity, lysosomal membrane damage, and reactive oxygen species generation — smaller particles caused more membrane disruption, larger particles caused more oxidative stress.[78]

Animal studies additionally report that ingested microplastics can reduce intestinal mucus secretion, weaken gut barrier integrity, and promote low-grade inflammation — effects that, if they hold in humans, could plausibly contribute to GI disease over time, though this hasn't been established in human populations yet.[79]

Translocation Beyond the Gut and Oral Cavity

Once a microplastic particle crosses an epithelial barrier — gut, lung, or oral mucosa — it doesn't necessarily stay put. Particles have been found in human blood, placenta, breast milk, liver (including cirrhotic tissue), lung tissue, and stool. This spread pattern matches what's seen in rodent studies, where orally administered polyethylene microplastics later turned up in serum and organs far from the digestive tract.[80]

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[75] Effects of Microplastic Exposure on Human Digestive, Reproductive, and Respiratory Health: A Rapid Systematic Review. PMC, NCBI, PMC11697325.

[76] Tamargo, A., Molinero, N., Reinosa, J.J., Alcolea-Rodriguez, V., Portela, R., Bañares, M.A., Fernández, J.F., & Moreno-Arribas, M.V. (2022). PET microplastics affect human gut microbiota communities during simulated gastrointestinal digestion, first evidence of plausible polymer biodegradation during human digestion. Scientific Reports, 12, 528. DOI: 10.1038/s41598-021-04489-w.

[77] Impact of microplastics on the human gut microbiome: a systematic review of microbial composition, diversity, and metabolic disruptions. (2025). PubMed, PMID: 40804621.

[78] Acute and Sub-Chronic Effects of Microplastics (3 and 10 µm) on the Human Intestinal Cells HT-29. PMC, National Center for Biotechnology Information (NCBI), PMC8198674.

[80] Toxicity Study and Quantitative Evaluation of Polyethylene Microplastics in ICR Mice. PMC, NCBI, PMC8839995.

Specific to oral care, a 2025 narrative review proposes that microplastic residue retained on oral mucosal surfaces could be capable of translocating into draining lymphatic tissue, with theoretical downstream effects including oxidative DNA damage, immune modulation, and mitochondrial dysfunction. The authors are upfront that this is a plausibility argument built from mechanistic and adjacent-tissue evidence — not a demonstrated pathway specific to toothpaste use.[81]

Inflammatory, Oxidative, and Cellular Effects

Three biological response patterns show up again and again across cellular and animal studies: oxidative stress (reactive oxygen species overwhelming the body's antioxidant defenses), inflammatory activation (cytokine release, immune cell recruitment), and direct cytotoxic or genotoxic effects at higher exposure levels.[82]

A controlled toxicity study in ICR mice given repeated oral doses of polyethylene microplastics found no change in body weight, but histopathology revealed foreign-body-associated inflammation in lung tissue, and Raman spectroscopy confirmed polyethylene particles had traveled to the lung, stomach, duodenum, ileum, and serum after oral dosing direct evidence that ingested PE microplastics can cross the gut barrier and spread systemically in a mammalian model.[83]

A 2025 systematic review of human-based evidence concluded that once internalized, microplastics may drive oxidative stress, inflammation, immune dysregulation, endocrine disturbance, and DNA damage while cautioning that most of this mechanistic detail still comes from animal/in-vitro work rather than confirmed human clinical outcomes.[84]

Endocrine-Disrupting Chemical Co-Exposure

Microplastics are rarely chemically "pure." Manufacturing additives — plasticizers, stabilizers, dyes aren't chemically bound to the polymer and can leach out over time. Reviews from the Endocrine Society and academic literature flag phthalates, bisphenol A (BPA), and polybrominated diphenyl ethers as common plastic-associated endocrine disruptors capable of interfering with hormone synthesis, transport, and receptor signaling.[85][86]

Microplastic particles are also hydrophobic, so they can adsorb additional contaminants heavy metals, persistent organic pollutants onto their surface, acting as a transport vector that delivers a chemical cocktail alongside the physical particle. Mammalian studies report documented effects on the hypothalamic-pituitary axis, thyroid function, and reproductive organs from plastic particles and their additives; phthalate exposure specifically has been linked to reduced thyroid weight and thyroid hormone receptor interference in developmental

[81] Micro- and Nanoplastics and the Oral Cavity: Implications for Oral and Systemic Health, Dental Practice, and the Environment — A Narrative Review. (2025). PMC, NCBI, PMC12470694.

[82] Impact of Microplastic Exposure on Human Health: A Systematic Review of Mechanisms, Biomarkers, and Clinical Outcomes. PMC, NCBI, PMC12848325.

[85] Plastics pose threat to human health: Plastics, EDCs, & Health report. (2020). Endocrine Society & International Pollutants Elimination Network (IPEN); lead author Jodi Flaws, University of Illinois at Urbana-Champaign.

[86] A review of the endocrine disrupting effects of micro and nano plastic and their associated chemicals in mammals. (2022). Frontiers in Endocrinology. PubMed, PMID: 36726457.

studies.[87][88] This is directly relevant to toothpaste: dental-material and oral-care polymers have been reported to leach residual monomers and additives including Bis-GMA, EGDMA, and phthalate-related compounds some with documented endocrine-disrupting, cytotoxic, or allergenic properties.[89]

Immune System

MPs, such as polystyrene, can elicit immunological reactions within the body. Introducing MPs into the bloodstream or tissues may elicit an inflammatory response. Chronic inflammation is associated with cardiovascular disease, autoimmune disorders, and cancer. Inhaled MPs may aggregate in pulmonary tissues, resulting in overwhelmed immune cells and a heightened risk of respiratory illnesses. Xu et al. found that MPs pose health risks to human tissues, with urban exposure assessed at 7.37 × 104 items/year for children and 1.06 × 105 items/year for adults. They highlighted the respiratory and immune systems as affected, linking atmospheric MPs to airborne pathogen risks, with Sphingomonas as a key mediator.

The over-activation of these pathways may lead to immune cell death, compromising immune defense and causing tissue damage. MPs interact with other environmental contaminants or microbial infections, enhancing their toxicity through surface binding, which amplifies immune responses. Furthermore, prolonged exposure to MPs is associated with injured immune system organs, particularly the spleen and liver, which can lead to fibrosis and inflammation[90].

Human Biomonitoring Evidence

Direct evidence that plastic particles circulate in the human body comes from biomonitoring studies. The landmark 2022 study by Leslie and colleagues detected polyethylene, PET, polystyrene-related polymers, and PMMA in the blood of most of a small cohort of healthy adults, at a mean combined concentration of roughly 1.6 micrograms of plastic per milliliter of blood.[91]

Independent follow-up studies using different techniques (μ-FTIR and pyrolysis-GC/MS) have confirmed microplastics in human blood at broadly similar, though variable, concentrations.[92][93]

One 2024 study went further and linked blood microplastic burden to changes in coagulation and inflammatory markers, including C-reactive protein and clotting function measures.[94]

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[88]Micro- and Nanoplastics as Disruptors of the Endocrine System — A Review of the Threats and Consequences Associated with Plastic Exposure. (2025). International Journal of Molecular Sciences (MDPI), 26(13), 6156.

[89]Exploring the sources and routes of micro- and nanoplastics from dental products and materials: their impact on human health — a systematic review. (2025). ScienceDirect.

[90] Abbas, G., Ahmed, U., & Ahmad, M. A. (2025). Impact of Microplastics on Human Health: Risks, Diseases, and Affected Body Systems. *Microplastics*, *4*(2), 23. https://doi.org/10.3390/microplastics4020023

[91]Leslie, H.A., van Velzen, M.J.M., Brandsma, S.H., Vethaak, A.D., Garcia-Vallejo, J.J., & Lamoree, M.H. (2022). Discovery and quantification of plastic particle pollution in human blood. Environment International, 163, 107199. DOI: 10.1016/j.envint.2022.107199.

[92]Microplastics in human blood: Polymer types, concentrations and characterisation using μFTIR. (2024). ScienceDirect.

[93]Quantitation of micro and nanoplastics in human blood by pyrolysis-gas chromatography–mass spectrometry. (2024). Microplastics and Nanoplastics, Springer Nature.

[94]Microplastic particles in human blood and their association with coagulation markers. (2024). Scientific Reports. DOI: 10.1038/s41598-024-81931-9.

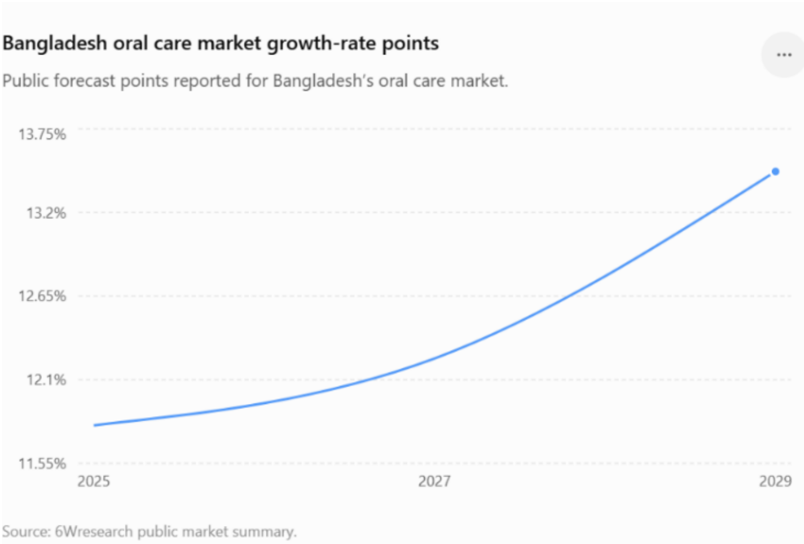
Taken together: human biomonitoring confirms microplastics do enter general circulation in a meaningful share of the population, and some studies now report associations with specific physiological markers. What's still unresolved is how much of that systemic burden is attributable to toothpaste specifically versus food packaging, drinking water, and household dust an open question for risk attribution, not a weakness in the underlying detection findings.

5. Market Trends in Bangladesh: Toothpaste and Oral Care Products

Bangladesh's toothpaste market is expanding within the wider oral care and personal care sector, driven by rising awareness of oral hygiene, growing purchasing power, wider retail access, e-commerce penetration, and increased competition between multinational and domestic brands. The Bangladesh oral care market is projected to grow during 2025–2031, with 6Wresearch estimating a CAGR of 3.16% for the forecast period[95]. This market trend is directly relevant to the present microplastics study because toothpaste is a universal daily-use product.

5.1. Growing Oral Care Market

Bangladesh's oral care market is experiencing steady growth due to increasing consumer awareness of dental hygiene, rising disposable income, urbanization, improved living standards, and the expansion of modern retail and e-commerce channels.

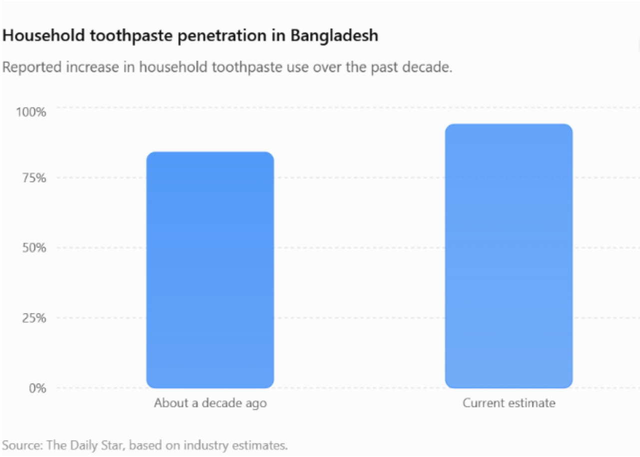


6Wresearch reports that the Bangladesh oral care market is expected to show a gradual growth-rate improvement, rising from 11.80% in 2025 to 13.47% in 2029, with a projected 12.24% growth rate by 2027 in the Asia regional comparison. This growth indicates that toothpaste and other oral care products are likely to remain high-volume consumer goods in Bangladesh. From an environmental perspective, this means that any formulation-related concern, including intentionally added microplastics, may become significant when scaled across millions of daily users.

[95] 6Wresearch. (2025). *Bangladesh Oral Care Market (2025–2031): Size, Trends, Growth, Forecast and Competitive Landscape*.

5.2. Toothpaste as the Core Oral Care Product

Toothpaste remains the most important oral care product category in Bangladesh because it is used daily and is closely linked to preventive dental hygiene. Market summaries identify toothpaste, toothbrushes, mouthwash/rinse, dental accessories, and denture products as key oral care categories, with toothpaste positioned as a major product segment.



Recent industry estimates reported by *The Daily Star* suggest that about 94% of households in Bangladesh now use toothbrushes and toothpaste in the morning, compared with traditional practices such as datun, charcoal, ash, and toothpowder in earlier decades. The same report states that household toothpaste penetration increased from 84% to 94% over the past decade, showing that toothpaste use has moved from an expanding category toward a mature but still growing consumer market[96].

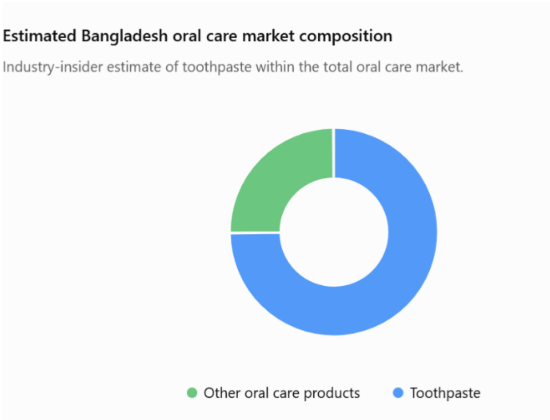
5.3. Market Size and Rural Demand

Industry insiders cited by *The Daily Star* estimate that Bangladesh's oral care market is around Tk 2,000 crore, of which toothpaste accounts for roughly Tk 1,500 crore.

The same source reports that rural consumers generate nearly 65% of oral care sales, while urban consumers account for the remaining share, indicating that toothpaste use is no longer limited to urban or higher-income households. This rural market penetration is important for microplastics assessment because environmental release from toothpaste is not concentrated only in large cities; it can occur through both urban drainage systems and rural wastewater pathways.

5.4. Product Diversification and Specialized Formulations

The Bangladesh oral care market is moving toward more diversified products, including herbal and natural oral care products, whitening toothpaste, fluoride-free formulations, mouthwash, and premium specialized oral care solutions.



This trend matters for microplastic research because specialized, whitening, polishing, gel-based, and cosmetic-oriented toothpaste formulations may use different abrasives, binders, stabilizers, texture enhancers, or decorative particles. As consumers shift toward premium, herbal, whitening, and specialized toothpaste products, ingredient-level transparency becomes increasingly important. Market growth should therefore be accompanied by stronger product surveillance, labeling requirements, and ingredient safety assessment.

[96] The Daily Star. (2026). From ash to toothpaste: Bangladesh's oral care shift.

5.5. Competition Between Multinational and Domestic Brands

Bangladesh's oral care market includes both multinational companies and domestic manufacturers. 6Wresearch identifies Colgate-Palmolive, Unilever, Procter & Gamble, GSK, Dabur, Himalaya Herbals, and local/private-label manufacturers as key market actors.

The Daily Star also reports that Bangladesh's toothpaste market now includes more than 14 competing players, reflecting strong competition and wide consumer choice across price segments. This competitive environment creates both challenges and opportunities. On one hand, multiple brands and product categories make market surveillance more complex. On the other hand, competition can encourage safer reformulation, microplastic-free product claims, improved labeling, and sustainability-focused marketing.

5.6. Local Manufacturing and Import Substitution

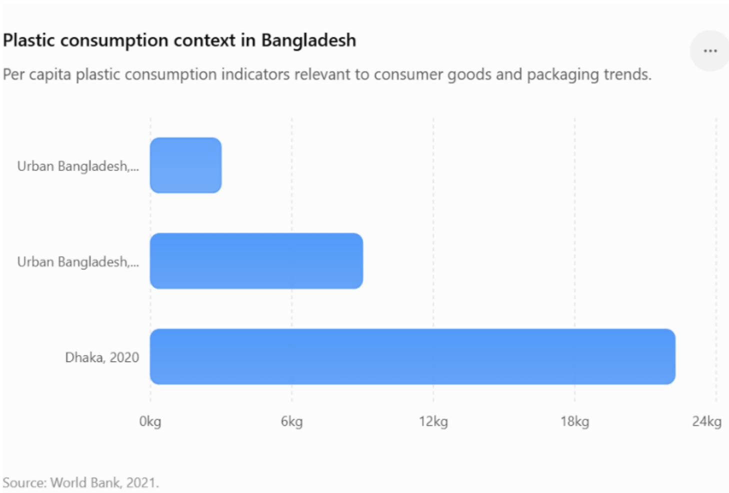
A major market trend is the shift from imported toothpaste toward local manufacturing. In 2023, ACI announced that it would invest Tk50 crore over three years in a joint venture with Colgate-Palmolive to produce Colgate toothpaste in Bangladesh. ACI's official company page states that Colgate-Palmolive ACI Bangladesh Pvt. Limited is a joint venture between Advanced Chemical Industries PLC and Colgate-Palmolive (Asia) Pte. Limited, aiming to manufacture and supply oral care products for Bangladesh's fast-expanding consumer market[97].

The Business Standard reported that Colgate had around 20% market share in Bangladesh in the early 2000s, but later declined to around 9%, partly because imported products faced high duties and taxes while competitors manufactured toothpaste locally[98].

This shift toward local manufacturing is important for regulatory engagement. Domestic production can make it easier for authorities, laboratories, and civil society organizations to engage manufacturers on formulation changes, safer substitutes, ingredient disclosure, and possible elimination of intentionally added microplastics.

5.7. Import Market and Trade Relevance

Dentifrices, including toothpaste, are internationally traded under HS Code 330610. World Bank WITS data show that Bangladesh imported dentifrices worth US$7.305 million in 2017, with a reported quantity of 2,185,880 kg.



World Bank WITS data also show that Bangladesh imported dentifrices worth US$7.838 million in 2018, with a reported quantity of 2,433,810 kg[99]. These import figures show that imported toothpaste and dentifrice products have been part of the Bangladeshi market. Therefore, any microplastic-related policy response should cover both locally manufactured and imported toothpaste products.

[97] ACI PLC. (2026). *Colgate-Palmolive ACI Bangladesh Pvt. Limited*.
[98] The Business Standard. (2023). *ACI to invest Tk50cr in a joint venture to produce Colgate toothpaste*.
[99] World Bank. (2021). Meeting Bangladesh's Plastic Challenge through a Multisectoral Approach.

5.8. Retail and E-Commerce Expansion

Oral care products in Bangladesh are sold through consumer stores, supermarkets, hypermarkets, convenience stores, pharmacies, dental dispensaries, and online platforms. 6Wresearch identifies retail and online distribution as important channels shaping the Bangladesh oral care market.

The expansion of e-commerce has improved access to a broader range of oral care products, including imported, premium, herbal, whitening, and niche toothpaste brands.

This trend is important for microplastic monitoring because online platforms can introduce a wider range of products into the market, including products that may not be consistently available in physical stores. Market surveillance should therefore include both offline and online product sampling.

5.9. Brand Positioning Around Health and Awareness

Major toothpaste brands in Bangladesh increasingly position themselves around dental health, confidence, freshness, children's brushing habits, and access to oral care. Unilever Bangladesh states that Pepsodent awareness programs encourage children and parents to brush twice daily using fluoride toothpaste and connect consumers with certified dentists. Closeup, another Unilever toothpaste brand, is positioned around freshness, confidence, youth appeal, and gel-based toothpaste identity in Bangladesh[100].

This health-focused brand positioning can be useful for microplastic reduction. If consumers are already responding to health, safety, and quality messages, brands may have an incentive to adopt microplastic-free formulations and communicate safer ingredient choices.

5.10. Sustainability and Plastic Pollution Context

Bangladesh's broader plastic pollution context makes toothpaste-derived microplastics a relevant environmental issue. The World Bank reports that annual per capita plastic consumption in urban Bangladesh tripled from 3 kg in 2005 to 9 kg in 2020.

The World Bank also reports that Bangladesh consumed 977,000 tons of plastic in 2020, of which only 31% was recycled, while a large share of plastic waste is dumped in landfills, water bodies, and rivers.

Dhaka's annual per capita plastic consumption reached 22.25 kg, more than three times the national urban average, and only 37.2% of Dhaka's plastic waste was recycled.

This plastic pollution context strengthens the case for addressing avoidable sources of microplastics in rinse-off consumer products. Toothpaste-derived microplastics are particularly important because they are directly washed into wastewater systems after use.

5.11. Implications for Microplastic Regulation

The growth of Bangladesh's toothpaste market creates a timely opportunity to address microplastics before product diversity and market volume expand further.

Market surveillance should include both local and imported toothpaste products, as the Bangladeshi market contains multinational brands, domestic manufacturers, private-label products, and imported products.

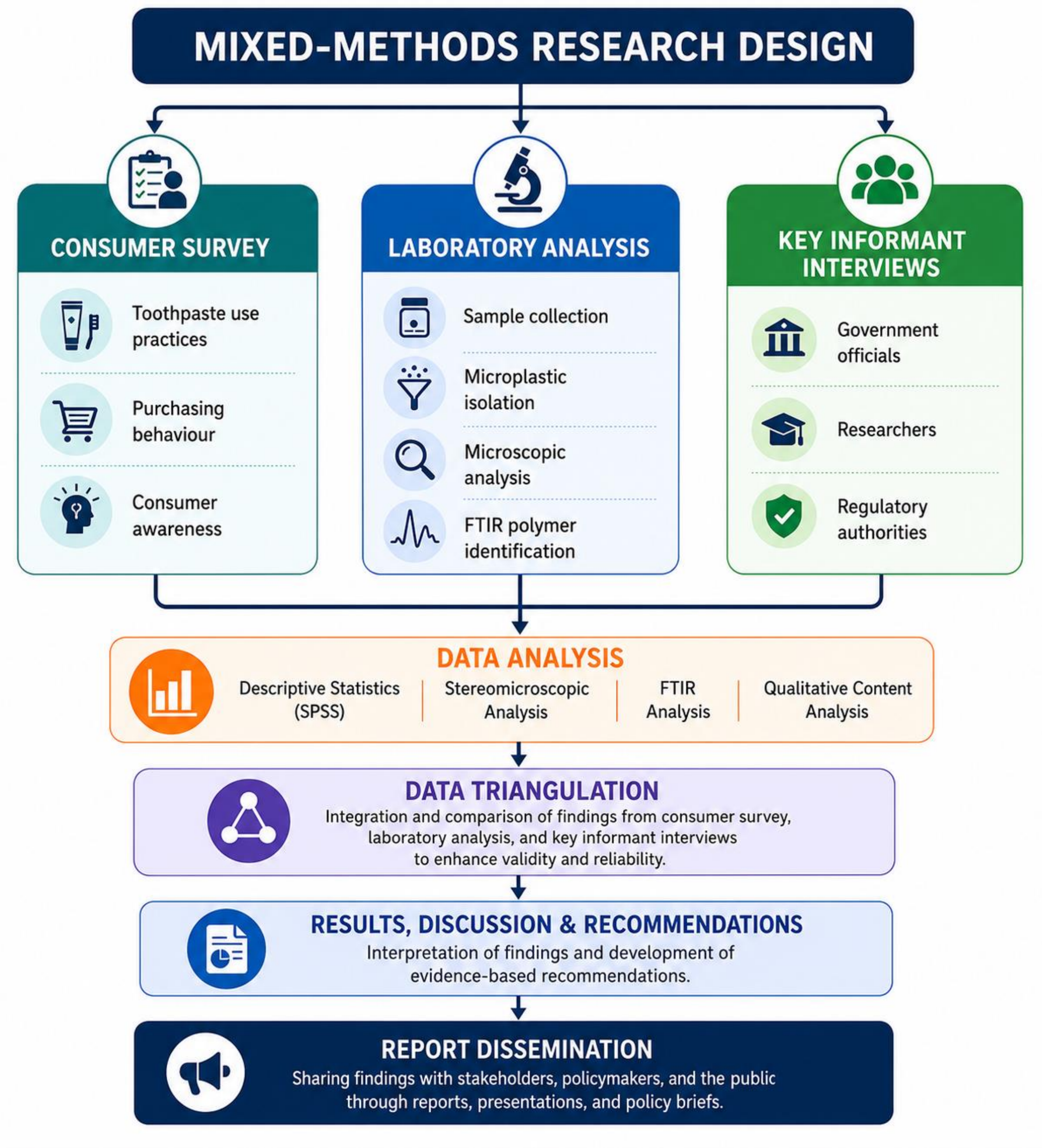
[100] Unilever Bangladesh.

Ingredient disclosure should be strengthened because synthetic polymers may be listed under technical chemical names rather than clearly identified as plastic or microplastic ingredients. The uploaded report notes that plastic ingredients are often difficult for consumers to identify because they may be listed using complex chemical terminology.

Microplastic control in toothpaste should be linked with broader product safety, plastic pollution reduction, and consumer protection strategies. Bangladesh’s existing plastic pollution burden, growing oral care market, and increasing demand for specialized toothpaste products make this issue both environmentally relevant and commercially timely.

6. Methodology

This study employed a mixed-methods research design over a twelve-month period, from July 2025 to June 2026, to investigate the occurrence of microplastics in toothpaste products available in the Bangladesh market, assess consumer awareness and toothpaste use practices, and explore stakeholder perspectives on regulatory, laboratory, and public health issues. The study integrated quantitative consumer survey data, laboratory analysis, and qualitative key informant interviews to provide comprehensive evidence on the occurrence of microplastics in toothpaste and the associated consumer awareness, regulatory, and public health context in Bangladesh.



Study Timeline

The study was conducted over a twelve-month period from July 2025 to June 2026. Activities were implemented in sequential phases as follows:

Study Activity	Timeline
Study design, protocol development, questionnaire preparation, and pre-testing	July to August 2025
Consumer survey	September to December 2025
Market Assessment, Toothpaste Sample Collection, and Laboratory Submission	January to February 2026
Laboratory analysis (sample preparation, microplastic isolation, microscopic examination, and FTIR analysis)	March to June 2026
Key Informant Interviews (KIIs)	April to May 2026
Report Writing, Finalization, and Dissemination	June and July 2026

The study comprised three complementary components

- Consumer Survey: to assess toothpaste use practices, purchasing behavior, awareness of microplastics in toothpaste, and consumer perceptions regarding environmentally friendly oral care products.
- Laboratory Analysis: To isolate, quantify, and characterize microplastic particles in toothpaste samples available in the Bangladesh market using microscopic examination and Fourier Transform Infrared Spectroscopy (FTIR) for polymer identification.
- Key Informant Interviews (KIIs): to explore stakeholder perspectives on the occurrence of microplastics in toothpaste, regulatory and policy issues, public health concerns, industry practices, and potential interventions to reduce microplastic exposure.

6.1 Consumer Survey

6.1.1 Study Design

A descriptive cross-sectional survey was conducted to assess consumers' oral hygiene practices, toothpaste purchasing behavior, awareness of microplastics in toothpaste, and perceptions regarding environmentally friendly oral care products.

6.1.2 Target Population

The target population comprised toothpaste users from different age groups across Bangladesh. As toothpaste is a universally used personal care product, the survey included respondents representing diverse age groups, genders, educational levels, occupations, monthly income categories, and residential settings (urban, suburban, and rural). For younger children who were unable to respond independently, information regarding toothpaste use was obtained from their parents or guardians.

6.1.3 Study Area

The study was conducted across urban, semi-urban, and rural areas of Bangladesh to capture a broad range of consumer perspectives and ensure geographic diversity. Data were collected from various public locations, including marketplaces, shopping malls, educational institutions, residential communities, healthcare facilities, and other community settings where eligible consumers were recruited. This approach enabled the inclusion of participants from diverse socioeconomic backgrounds and different geographic settings, thereby providing a comprehensive and representative understanding of consumer perspectives across the country.

6.1.4 Study Period

The consumer survey was conducted from September to December 2025.

6.1.5 Pre-testing of the Questionnaire

To observe the overall scenario, including questionnaire information, possible sampling techniques, and the approximate non-response rate related to the study, we first performed a pre-test among a small group of respondents. The pre-testing was conducted in markets located in Mohammadpur, Dhaka.

6.1.6 Sample Size

A total of 2760 respondents participated in the consumer survey. Of these, 1,437 respondents were recruited from Dhaka Division and its adjacent urban and semi-urban areas, while the remaining respondents were distributed across Sylhet (316), Chattogram (280), Rajshahi (227), Rangpur (190), Mymensingh (123), and Khulna and Barishal divisions (187), covering both urban and rural areas. This distribution ensured broad geographic representation and captured diverse demographic characteristics and consumer perspectives across Bangladesh.

6.1.7 Sampling Technique

A purposive sampling technique was employed to recruit eligible participants. Individuals were selected based on their regular use of toothpaste and their willingness to participate in the survey.

6.1.8 Data Collection

6.1.8.1 Survey Questionnaire

Primary data were collected using a semi-structured questionnaire developed specifically for this study following a review of relevant scientific literature and the study objectives. The questionnaire was designed to collect quantitative data on consumer knowledge, attitudes, and practices related to toothpaste use and microplastics.

The questionnaire comprised the following sections:

- Socio-demographic characteristics of respondents
- Toothpaste use practices and brushing frequency
- Toothpaste purchasing behavior and preferred brands
- Awareness and knowledge of microplastics in oral care products

6.1.8.2 Data Collection Procedure

Data were collected through face-to-face interviews conducted by trained data collectors using the semi structured questionnaire. Before each interview, respondents were informed about the objectives of the study, the voluntary nature of participation, and the confidentiality of their responses. Verbal informed consent was obtained prior to data collection.

6.1.9 Data Analysis

6.1.9.1 Data Entry and Cleaning

Completed questionnaires were checked for completeness and consistency prior to data entry. Survey data were entered into IBM SPSS Statistics version 27.0 for analysis. The dataset was cleaned by identifying missing values, duplicate entries, and inconsistent responses to ensure data quality.

6.1.9.2 Statistical Analysis

Descriptive statistical analyses were performed to summarize respondent characteristics and survey findings. Categorical variables were presented as percentages. Survey findings were presented using tables and graphical illustrations, including bar charts and pie charts.

6.1.10 Ethical Considerations

Participation in the survey was voluntary. All respondents were informed about the objectives of the study prior to data collection. Verbal informed consent was obtained from each participant. Confidentiality and anonymity of respondents were maintained throughout data collection, analysis, and reporting.

6.2 Laboratory Analysis

Laboratory analysis was conducted between March and June 2026 at the Laboratory of Environmental Health and Ecotoxicology (EHE), Department of Environmental Sciences, Jahangirnagar University, Savar, Dhaka, Bangladesh, following standardized analytical procedures. Fourier Transform Infrared Spectroscopy (FT-IR) analysis for polymer identification was conducted at the Wazed Miah Science Research Center (WMSRC), Jahangirnagar University, Savar, Dhaka, Bangladesh. The laboratory analysis aimed to isolate, identify, quantify, and characterize microplastic particles in commercially available toothpaste samples available in Bangladeshi market.

6.2.1 Sample Collection

A total of 34 toothpaste samples, including locally manufactured and imported products available in the Bangladesh market, were collected for laboratory analysis. Samples were selected from commonly available products purchased from retail outlets, super shop and wholesale market. Each toothpaste sample was assigned a unique identification code (TP-01 to TP-34) before laboratory analysis. Product information, including brand name, manufacturer, country of manufacture, importer, place of sale, batch number, declared ingredients, and certification status (BSTI/ISO/BDS), was recorded from the product labels.

6.2.2 Microplastic Isolation and Extraction

Microplastic particles were isolated from toothpaste samples using chemical digestion and density separation methods. Briefly, 5.0 g of each toothpaste sample was dispersed in 50 mL of deionized water and mixed thoroughly to obtain a uniform suspension. The samples were treated with 10 mL of 30% (v/v) hydrogen peroxide (H_2O_2) and allow to digest at ambient temperature for 72 hours to remove organic binders and flavoring oils.

After digestion, density separation was performed by adding a zinc chloride ($ZnCl_2$) solution (ρ = 1.7 g cm^{-3}), and the mixture was left undisturbed for 24 hours to allow flotation of high-density polymers. The suspension was then centrifuged at 4000 rpm for 15 min to separate the lighter plastic fraction from heavier inorganic abrasives. The resulting supernatant was collected and vacuum-filtered through a 0.45 µm cellulose nitrate membrane filter.

6.2.3 Microscopic Examination and Quantification

The membrane filters were dried and examined under a stereomicroscope (45× magnification) for the visual identification and enumeration of suspected microplastic particles. Particles were identified based on their morphological characteristics, and the number of particles observed was recorded for each sample. Microplastic abundance was expressed as particles per 100 g of toothpaste.

6.2.4 Fourier Transform Infrared Spectroscopy (FTIR)

Representative microplastic particles isolated from selected toothpaste samples were analyzed using Fourier Transform Infrared Spectroscopy (FT-IR) *(IRPrestige-21, Shimadzu Corporation, Kyoto, Japan)* to identify polymer types. Spectra were acquired in transmission mode over a wavenumber range of 400–4000 cm^{-1} at a spectral resolution of 4 cm^{-1}, with each spectrum averaged over 16 scans to improve the signal-to-noise ratio. For sample preparation, plastic particles were carefully scraped, mixed with potassium bromide (KBr), and compressed into pellets under 10–12 tons of pressure for 30 s. Polymer identification were performed by comparing the obtained spectra with characteristic absorption bands reported in the literature[101] (Jung et al., 2018). Spectral processing and analysis were conducted using OriginPro 2026.

6.2.5 Quality Assurance and Quality Control

Laboratory procedures were conducted under clean working conditions to minimize contamination. All glassware and laboratory equipment were thoroughly rinsed with deionized water before use, and samples were handled carefully throughout the analytical process to reduce the risk of external contamination.

6.3 Key Informant Interviews (KII)

6.3.1 Study Design

A qualitative Key Informant Interview (KII) approach was employed to obtain expert perspectives on microplastics in toothpaste, including laboratory capacity, regulatory issues, research gaps, public health concerns, and potential policy interventions in Bangladesh.

6.3.2 Selection of Key Informants

Key informants were purposively selected based on their expertise and institutional responsibilities related to product regulation, laboratory analysis, environmental science, and public health. Interviews were conducted with representatives from the Bangladesh Standards and Testing Institution (BSTI), the Bangladesh Council of Scientific and Industrial Research (BCSIR), and the Bangladesh University of Engineering and Technology (BUET). These institutions were selected for their expertise in product quality regulation, analytical testing, environmental research, and the scientific assessment of microplastics.

[101] Jung, M. R., Horgen, F. D., Orski, S. V., Rodriguez C., V., Beers, K. L., Balazs, G. H., Jones, T. T., Work, T. M., Brignac, K. C., Royer, S.-J., Hyrenbach, K. D., Jensen, B. A., & Lynch, J. M. (2018). Validation of ATR FT-IR to identify polymers of plastic marine debris, including those ingested by marine organisms. *Marine Pollution Bulletin, 127*, 704–716. https://doi.org/10.1016/j.marpolbul.2017.12.061

6.3.3 Data Collection

Data were collected between April and May 2026 through in-person and or virtually semi-structured interviews using a pre-tested interview guide. Each interview lasted approximately 20–30 minutes. Verbal informed consent was obtained from all participants prior to the interviews.

6.3.4 Data Analysis

Interview responses were analyzed using qualitative content analysis. Responses were reviewed, compared, and organized according to the study objectives and key areas of inquiry, including regulatory frameworks, laboratory capacity, analytical methods, research gaps, public health concerns, and recommendations for strengthening microplastic monitoring and management in Bangladesh. The findings were synthesized to provide complementary evidence to the consumer survey and laboratory analysis.

6.4 Data Triangulation

Findings from the consumer survey, laboratory analysis, and key informant interviews were integrated to provide a comprehensive understanding of microplastics in toothpaste in Bangladesh. The triangulation of these data sources enhanced the validity of the findings by allowing interpretation from consumer, scientific, regulatory, and public health perspectives.

6.5 Limitations of the Study

FTIR analysis was conducted only on selected suspected microplastic particles isolated from the toothpaste samples with the highest suspected microplastic content due to resource constraints.

7. Results and Discussion

7.1 Consumer Survey Findings

7.1.1 Socio-demographic Characteristics of the Respondents

The majority of respondents (35.8%) were aged 20–30 years, followed by those aged 31–40 years (31.7%). Respondents aged 1–19 years collectively accounted for 12.5% of the study population. Female respondents constituted 53.1% of the study population, while 46.3% were male. In terms of educational qualification, 31.9% of respondents had a graduate degree or higher, followed by secondary education (23.1%), primary education (20.6%), higher secondary education (13.8%), and no formal education (10.6%). Regarding monthly household income, the largest proportion of respondents reported an income of BDT 30,000–50,000 (31.5%), followed by BDT 50,000–100,000 (30.4%). Overall, the survey included respondents from diverse age groups, educational backgrounds, income levels, and geographic settings, providing a broad representation of toothpaste consumers in Bangladesh.

Table 3. Socio-demographic Characteristics of the Respondents

Variable	Category	Percentage (%)
Age	1–5 years	1.8
	6 –9 years	2.7
	10–19 years	8.0
	20–30 years	35.8
	31–40 years	31.7
	41–50 years	13.1
	>50 years	6.9
Gender	Male	46.3
	Female	53.1
	Other/Prefer not to say	0.6
Education	No formal education	10.6
	Primary	20.6
	Secondary	23.1
	Higher secondary	13.8
	Graduate and above	31.9
Monthly Household Income (BDT)	3,000–15,000	9.1
	15,000–30,000	15.6
	30,000–50,000	31.5
	50,000–100,000	30.4
	100,000–200,000	9.1
	200,000 and above	4.3

7.1.2 Oral Hygiene Practices

Among the respondents, 90.6% reported regular use of a toothbrush as part of their daily oral hygiene routine, whereas 9.4% reported not using a toothbrush regularly. Similarly, 82.5% reported regular use of toothpaste, while 17.5% reported using other oral hygiene products, such as tooth powder or other cleaning agents.

Table 4. Regular use of oral hygiene products among respondents

Oral hygiene practice	Percentage (%)
Toothbrush use	
Regular use of toothbrush	90.6
Does not use a toothbrush regularly	9.4
Toothpaste use	
Regular use of toothpaste	82.5
Uses other oral hygiene products*	17.5

*Other oral hygiene products include tooth powder and other cleaning agents reported by the respondents.

7.1.3 Frequency of Toothpaste Use per Day

The majority of respondents (56.9%) reported using toothpaste once per day, followed by 40.6% who reported using toothpaste twice per day. A small proportion (2.5%) reported using toothpaste more than twice per day.

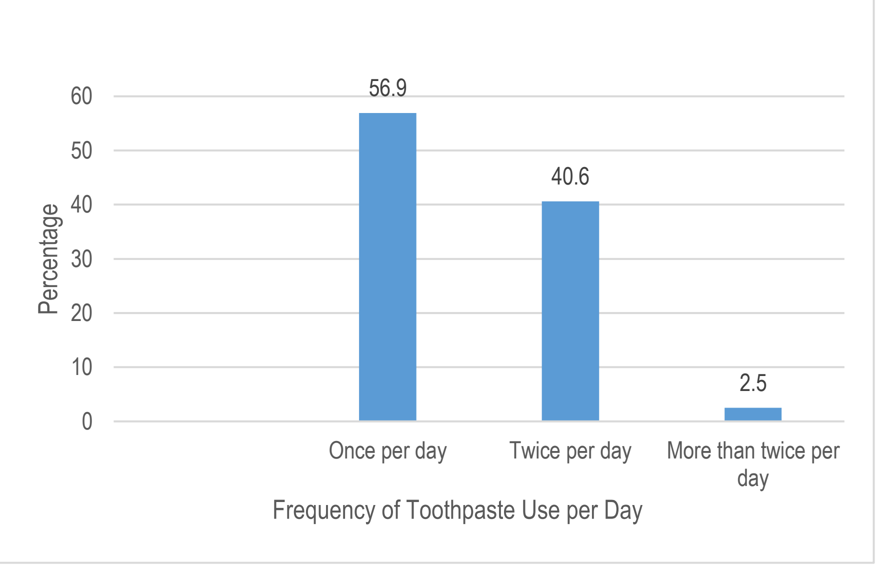


Figure 1. Frequency of toothpaste use among respondents

7.1.4 Commonly Used Toothpaste Brands

The survey showed that MediPlus was the most commonly used toothpaste brand, reported by 35.6% of respondents. This was followed by CloseUp (14.4%), Pepsodent (13.8%), Colgate (11.3%), Sensodyne (7.5%), and Oral-B (6.3%). The remaining 11.3% of respondents reported using other local or less commonly used brands. These findings indicate that consumers in Bangladesh use a diverse range of available toothpaste brands.

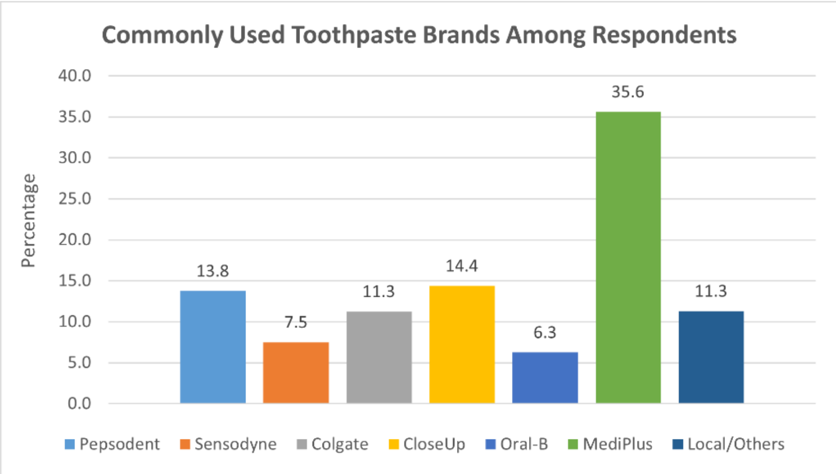


Figure 2. Commonly used toothpaste brands among respondents

7.1.5 Awareness of Microplastics in Toothpaste and Toothbrushes

When asked about microplastics in oral care products, majority (41.9%) of respondents reported that they had never heard of microplastics in toothpaste or toothbrushes. Approximately 31.3% indicated that they had heard about microplastics but were not familiar with the issue, whereas 26.9% reported being aware of the presence of microplastics in oral care products

The distribution of responses indicates different levels of awareness regarding microplastics in oral care products among the respondents.

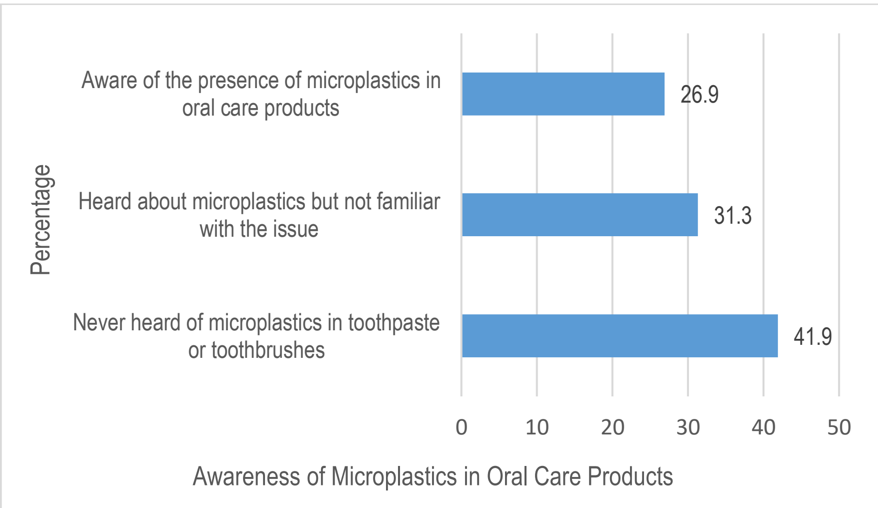


Figure 3. Awareness of microplastics in toothpaste and toothbrushes

7.2 Lab Analysis

7.2.1 Presence of Microplastics in Toothpaste Samples

Microplastic particles were detected in 26 (76.5%) of the 34 available toothpaste samples analyzed, while 8 (23.5%) samples showed no detectable microplastic particles.

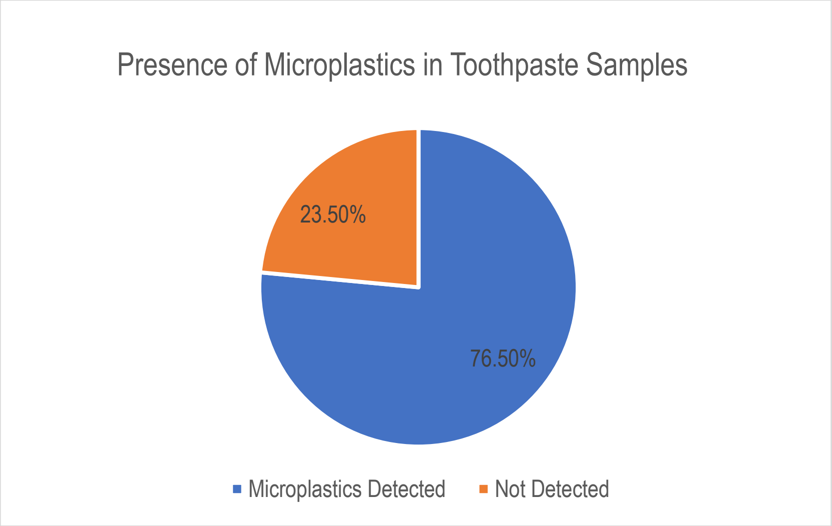


Figure 4. Presence of Microplastics in Toothpaste Samples

7.2.2 Country of Origin and Characteristics of the Toothpaste Samples

A total of 34 available toothpaste samples representing 19 brands were collected from retail outlets, supermarkets, and wholesale markets in Bangladesh. The samples included products manufactured in Bangladesh (n = 25), India (n = 5), Thailand (n = 2), and Vietnam (n = 2). The selected products comprised both locally manufactured and imported toothpastes and represented a range of formulations for adults, children, whitening, herbal, fluoride, and sensitive teeth.

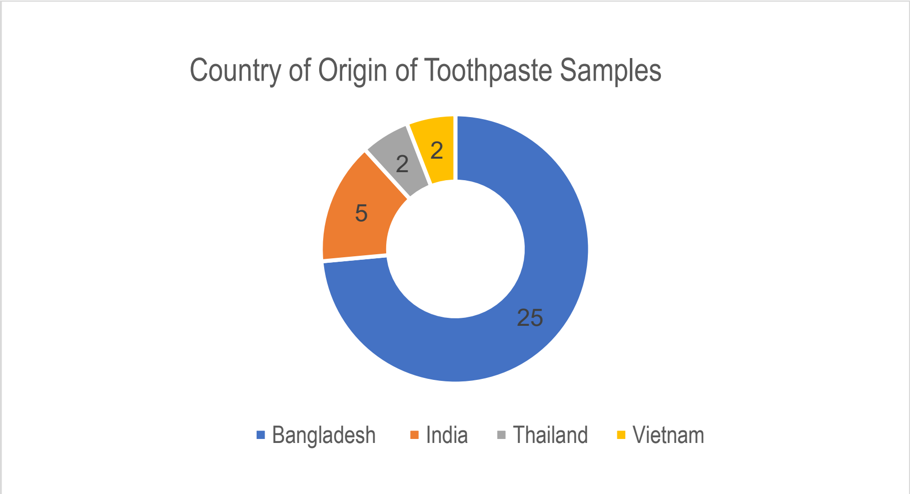


Figure 5. Distribution of toothpaste samples according to the country of manufacture (n = 34)

7.2.3 Summary statistics of Microplastic Concentrations

Table 5 summarizes the distribution of microplastic concentrations in the 34 toothpaste samples analyzed in this study, with non-detected (ND) samples assigned a value of 0 particles per 100 g. Microplastic concentrations ranged from 0 to 320 particles per 100 g, with a mean concentration of 52.9 particles per 100 g. The findings indicate considerable variation in the occurrence of microplastics among the analyzed toothpaste products, reflecting differences in product formulation and composition.

Table 5. Descriptive statistics of microplastic concentrations in the analyzed toothpaste samples (n = 34)

Statistic	Value (particles per 100 g)
Number of samples	34
Minimum	0
Maximum	320
Mean	52.9
Range	0 - 320

7.2.4 Characteristics of Toothpaste Samples and Microplastic Detection

A total of 34 toothpaste samples representing 19 brands available in the Bangladesh market were analyzed. Table 6 summarizes the characteristics of the analyzed toothpaste samples and the detected microplastic concentrations.

Findings

- Microplastic particles were detected in 26 of the 34 (76.5%) toothpaste samples collected from the Bangladesh market, while no detectable microplastic particles were found in the remaining 8 samples (23.5%).
- Microplastic concentrations ranged from **20 to 320 particles per 100 g** of toothpaste.
- **The highest microplastic concentrations were detected in**
    - Mediplus Fluoride Gel (TP-15) – 320 particles/100 g
    - Close Up Red Hot (TP-03) – 160 particles/100 g
    - Closeup Menthol Fresh (TP-21) – 160 particles/100 g
    - Kodomo Ultra Shield Formula (Streberry) (TP-16) – 140 particles/100 g
    - Signal Green Tea (TP-07) – 120 particles/100 g
    - Pepsodent Advance Salt (TP-05) – 100 particles/100 g
    - Himalaya Complete Care (TP-30) – 100 particles/100 g
    - Sensodyne Fresh Mint (TP-06) – 80 particles/100 g

- None of the analyzed toothpaste products explicitly declared the presence of microplastics on their ingredient labels.
- Detectable microplastic particles were found in both **locally manufactured and imported** toothpaste products, indicating that their occurrence was not limited to products from a particular country of origin.

- Among the **six toothpaste products for children**, **four (66.7%)** contained detectable microplastic particles, with concentrations ranging from **20 to 140 particles per 100 g**, while two products showed no detectable microplastic particles. Among the six toothpaste four (66.7%) contained detectable microplastic particles: Kodomo Ultra Shield Formula (Strawberry) (140 particles/100 g), Meril Baby (Strawberry) (60 particles/100 g), Meril Baby (Orange) (40 particles/100 g), and Pepsodent Kids (Orange) (20 particles/100 g). Parachute Just for Baby and Kodomo (Orange) showed no detectable microplastic particles.

The findings demonstrate that microplastic particles are present in a substantial proportion of available toothpaste products in Bangladesh, including products intended for children, highlighting the need for strengthened product monitoring, improved ingredient transparency, and further investigation into potential sources of contamination.

Table 6. Characteristics of Toothpaste Samples and Microplastic Concentration

No.	Product/ Brand Name	Manufacturer	Country of Origin	Microplastics Declared on Label	MPs Concentration (particles per 100 g)
TP 01	Parodontax Expert Gum Care	Global Health Care Products	India	No	ND
TP 02	Dentin Gel Toothpaste	Advance Personal Care Limited	Bangladesh	No	20
TP 03	Close Up Red Hot	Unilever Bangladesh	Bangladesh	No	160
TP 04	Pepsodent Sensitive Expert	Unilever Bangladesh	Bangladesh	No	60
TP 05	Pepsodent Advance Salt	Unilever Bangladesh	Bangladesh	No	100
TP 06	Sensodyne Fresh Mint	Global Health Care Products	India	No	80
TP 07	Signal Green Tea	Unilever Vietnam Int. Company Limited	Vietnam	No	120
TP 08	Pepsodent Kids (Orange)	Unilever Bangladesh	Bangladesh	No	20
TP 09	am.pm. Herbal Toothpaste	Kohinoor Chemical	Bangladesh	No	40
TP 10	Zenfresh	Dabur Bangladesh Private Limited	Bangladesh	No	ND
TP 11	Close Up Lemon Sea Salt	Unilever Bangladesh	Bangladesh	No	20
TP 12	Brush Up Whitening Gel	Anfords Bangladesh Limited	Bangladesh	No	20
TP13	White Plus Red	Square Toiletries Ltd.	Bangladesh	No	60
TP 14	White Plus Pro Sensitive	Square Toiletries Ltd.	Bangladesh	No	20

TP 15	Mediplus Fluoride Gel	Anfords Bangladesh Limited	Bangladesh	No	320
TP 16	Kodomo Ultra Shield Formula (Streberry)	LION Co., Ltd.	Thailand	No	140
TP 17	Parachute Just for Baby (Mango)	Marico Bangladesh Limited	Bangladesh	No	ND
TP 18	White Plus Pro Sensitive Gel	Square Toiletries Ltd.	Bangladesh	No	60
TP 19	Mediplus DS	Anfords Bangladesh Limited	Bangladesh	No	40
TP 20	Pepsodent Germicheck+	Unilever Bangladesh Limited	Bangladesh	No	40
TP 21	Closeup Menthol Fresh	Unilever Bangladesh Limited	Bangladesh	No	160
TP 22	Meril Baby (Strawberry)	Square Toiletries Ltd.	Bangladesh	No	60
TP 23	Meril Baby (Orange)	Square Toiletries Ltd.	Bangladesh	No	40
TP 24	Magic Herbal	Square Toiletries Ltd.	Bangladesh	No	40
TP 25	Meswak	Dabur Bangladesh Private Limited	Bangladesh	No	40
TP 26	Signal Whitening	Unilever Vietnam Int. Company Limited	Vietnam	No	60
TP 27	Sensodyne Fresh Gel	Global Health Care Products	India	No	ND
TP 28	Colgate MaxFresh	Colgate-Palmolive (India) Ltd.	India	No	ND
TP 29	Close-Up Red-Hot Zinc Fresh Technology	Unilever Bangladesh Limited	Bangladesh	No	ND
TP 30	Himalaya Complete Care	Himalaya Wellness Bangladesh Ltd.	Bangladesh	No	100
TP 31	Kodomo (Orange)	LION Co., Ltd.	Thailand	No	ND
TP 32	Colgate Active Salt	Colgate-Palmolive (India) Ltd.	India	No	ND
TP 33	Mediplus TGP Formula Toothpaste	Anfords Bangladesh Limited	Bangladesh	No	60
TP 34	Closeup Menthol Fresh Sachet	Unilever Bangladesh Limited	Bangladesh	No	40

7.2.5 Microplastic Detection by Country of Origin

The 34 toothpaste samples analyzed in this study originated from Bangladesh, India, Thailand, and Vietnam. Of the total samples, 25 (73.5%) were manufactured in Bangladesh, 5 (14.7%) in India, 2 (5.9%) in Thailand, and 2 (5.9%) in Vietnam. Detectable microplastic particles were identified in 22 of the 25 toothpaste samples manufactured in Bangladesh, 1 of the five samples from India, 1 of the two samples from Thailand, and both samples from Vietnam. Overall, microplastics were detected in toothpaste products originating from all four countries, indicating that both locally manufactured and imported toothpaste products available in the Bangladesh market contained detectable microplastic particles. Table 7 summarizes the detection of microplastic particles in toothpaste samples by country of origin.

Table 7. Detection of microplastic particles in toothpaste samples by country of origin

Country	Samples	MPs Detected	ND
Bangladesh	25	22	3
India	5	1	4
Thailand	2	1	1
Vietnam	2	2	0

7.2.6 Microplastic Concentration in Children's Toothpaste

A total of six toothpaste products for children were included in the study. Microplastic particles were detected in four (66.7%) of the products, while two (33.3%) showed no detectable (ND) microplastic particles.

Among the positive samples, microplastic concentrations ranged from 20 to 140 particles per 100 g of toothpaste. The highest concentration was observed in Kodomo Ultra Shield Formula (Strawberry Flavour) (TP-16) (140 particles per 100 g), followed by Meril Baby (Strawberry Flavour) (TP-22) (60 particles per 100 g), Meril Baby (Orange Flavour) (TP-23) (40 particles per 100 g), and Pepsodent Kids (Orange) (TP-08) (20 particles per 100 g). No detectable microplastic particles were found in Parachute Just for Baby (TP-17) and Kodomo (Orange) (TP-31).

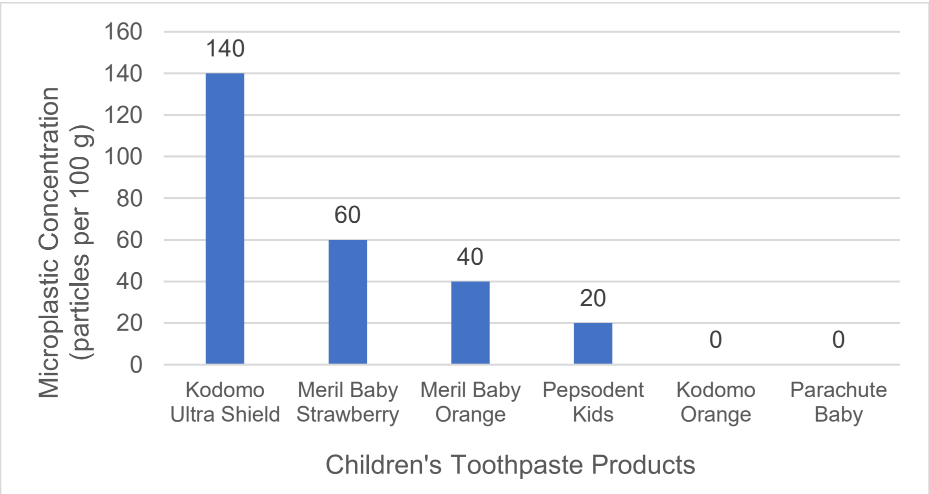


Figure 6. Microplastic concentration in toothpaste products for children

7.3 Polymer Identification by Fourier Transform Infrared Spectroscopy (FTIR)

Representative microplastic particles isolated from three toothpaste samples (TP-03, TP-15, and TP-21) were analyzed using Fourier Transform Infrared Spectroscopy (FTIR) to confirm their polymer composition. Polymer identification was performed by comparing the obtained spectra with reference spectra available in the FTIR spectral library and characteristic absorption bands reported in the literature.

The representative particle isolated from TP-03 (Close Up Red Hot) exhibited characteristic absorption bands at 2920, 2850, 1651, 1402, 1072, and 752 cm^{-1}, confirming the presence of Ethylene Vinyl Acetate (EVA) (Figure 7). The absorption bands observed at 2920 and 2850 cm^{-1} correspond to C–H stretching vibrations of aliphatic hydrocarbons, while the peaks at 1651, 1402, 1072, and 752 cm^{-1} are characteristic of EVA.

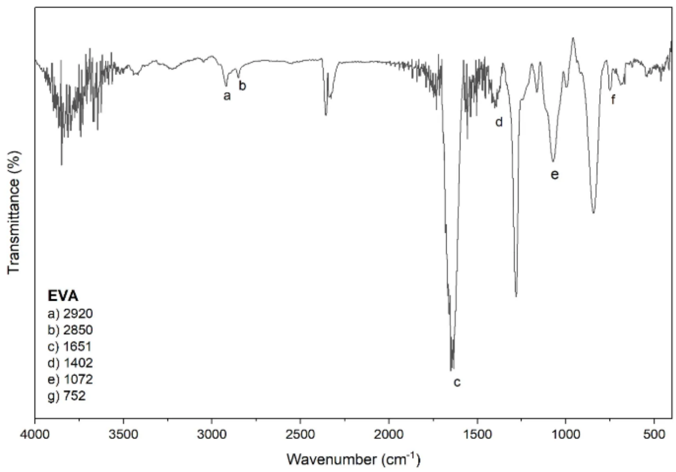


Figure 7. FTIR spectrum of the representative microplastic particle isolated from TP-03 (Close Up Red Hot) identified as Ethylene Vinyl Acetate (EVA)

The representative particle isolated from TP-15 (Mediplus Fluoride Gel) displayed characteristic absorption bands at 2920, 2851, 1456, 1379, 748, and 682 cm^{-1}, confirming the presence of Low-Density Polyethylene (LDPE) (Figure 8). The spectrum exhibited the characteristic C–H stretching and bending vibrations associated with polyethylene-based polymers, which are consistent with reference spectra for LDPE.

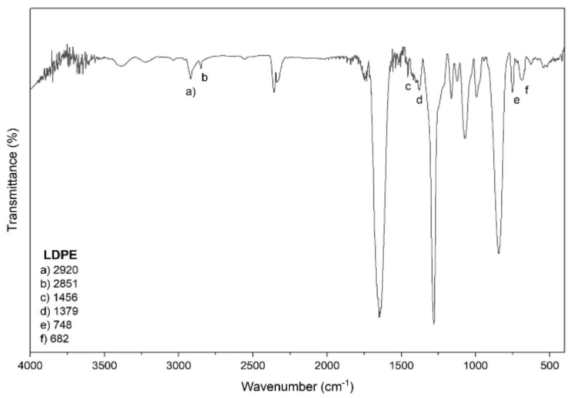


Figure 8. FTIR spectrum of the representative microplastic particle isolated from TP-15 (Mediplus Fluoride Gel) identified as Low-Density Polyethylene (LDPE).

Similarly, the representative particle isolated from TP-21 (Closeup Menthol Fresh) exhibited characteristic absorption bands at 2928, 2850, 1456, 752, and 690 cm^{-1}, confirming the presence of High-Density Polyethylene (HDPE) (Figure 9). The spectral pattern closely matched the reference spectrum of HDPE, indicating that the isolated particle was composed of polyethylene.

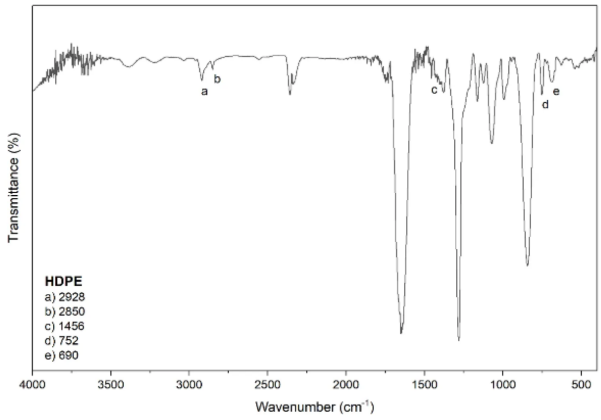


Figure 9. FTIR spectrum of the representative microplastic particle isolated from TP-21 (Closeup Menthol Fresh) identified as High-Density Polyethylene (HDPE)

Overall, FTIR analysis confirmed that the representative particles isolated from the selected toothpaste samples were synthetic polymer materials. Three different polymer types were identified, namely Ethylene Vinyl Acetate (EVA), Low-Density Polyethylene (LDPE), and High-Density Polyethylene (HDPE). These findings provide chemical confirmation that the particles observed during microscopic examination were microplastics and demonstrate the presence of different polymer types in available toothpaste products.

Table 8. Polymer identification of representative microplastic particles isolated from selected toothpaste samples

Sample ID	Toothpaste Product	Polymer Identified	Characteristic Absorption Bands (cm^{-1})
TP-03	Close Up Red Hot	Ethylene Vinyl Acetate (EVA)	2920, 2850, 1651, 1402, 1072, 752
TP-15	Mediplus Fluoride Gel	Low-Density Polyethylene (LDPE)	2920, 2851, 1456, 1379, 748, 682
TP-21	Closeup Menthol Fresh	High-Density Polyethylene (HDPE)	2928, 2850, 1456, 752, 690

8. Recommendations

Develop National Regulatory Standards

Develop national standards and regulatory guidelines for microplastics in toothpaste and other oral care products, including clear definitions, permissible limits (where appropriate), and compliance requirements.

Prohibit the Use of Intentionally Added Microplastics in Toothpaste

Introduce regulations to prohibit the manufacture, import, distribution, and sale of toothpaste containing intentionally added microplastics or synthetic polymer microbeads. Manufacturers should be encouraged to replace plastic-based ingredients with safe, biodegradable, and environmentally sustainable alternatives.

Establish Mandatory Testing and Market Surveillance

Introduce mandatory pre-market and post-market testing of toothpaste products for microplastic contamination using internationally accepted analytical methods such as FTIR and Raman spectroscopy.

Integrate microplastic screening into routine product quality assessment and market surveillance programmes for both locally manufactured and imported products.

Strengthen Laboratory Capacity

Invest in laboratory infrastructure, advanced analytical equipment, standardized testing protocols, quality assurance systems, and technical training to strengthen national capacity for microplastic detection, identification, and quantification.

Improve Ingredient Transparency and Product Labelling

Require manufacturers to disclose all synthetic polymer ingredients using clear and consumer-friendly terminology.

Introduce voluntary or mandatory "Microplastic-Free" product labeling based on verified testing and established certification criteria.

Strengthen Institutional Coordination

Promote effective coordination among regulatory authorities, research institutions, academic organizations, industry representatives, and consumer protection bodies to ensure a harmonized approach to regulation, monitoring, research, and enforcement.

Promote Research and National Monitoring

Establish a long-term national monitoring programme for microplastics in toothpaste and other personal care products.

Support multidisciplinary research on environmental fate, human exposure, health implications, wastewater pathways, and safer alternative ingredients.

Promote Industry Transition to Sustainable Alternatives

Encourage manufacturers to reformulate toothpaste by eliminating intentionally added microplastics and adopting environmentally sustainable, biodegradable alternatives through innovation, research, and voluntary industry commitments.

Enhance Consumer Awareness

Implement nationwide awareness programmes to improve public understanding of microplastics in oral care products and encourage informed purchasing decisions and environmentally responsible consumer behavior.

Align with International Best Practices

Harmonize national regulations with emerging international best practices and global efforts to reduce plastic pollution by progressively phasing out intentionally added microplastics in toothpaste and other rinse-off personal care products.

9. Conclusion

This study provides the comprehensive scientific evidence of microplastic contamination in available toothpaste products in Bangladesh and establishes an important baseline for future regulatory action. Microplastic particles were detected in more than three-quarters (76.5%) of the toothpaste samples analyzed, including products available for children, while FTIR analysis confirmed the presence of synthetic polymers such as LDPE, HDPE, and EVA. These findings demonstrate that toothpaste represents a previously overlooked but continuous source of primary microplastic pollution in Bangladesh.

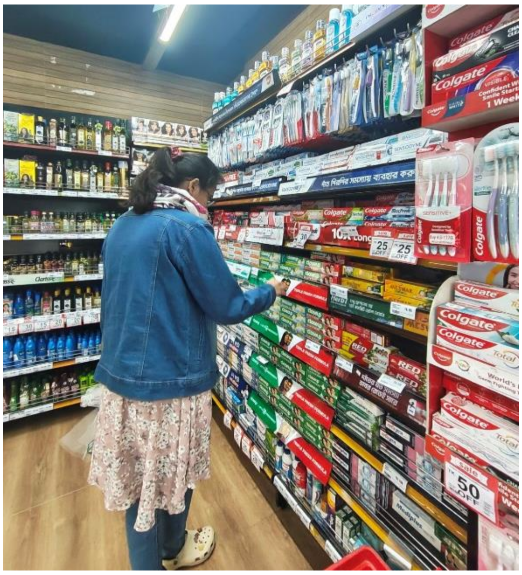
The study also highlights significant regulatory gaps. Bangladesh currently has **no specific legislation, standards, testing protocols, or routine monitoring system** addressing microplastics in toothpaste, despite the widespread daily use of these products and growing international regulatory action to eliminate intentionally added microplastics from oral care products. Combined with limited consumer awareness and inadequate ingredient transparency, these gaps underscore the urgent need for evidence-based policy intervention.

Considering the persistence of microplastics in the environment, their continuous release into wastewater during daily toothbrushing, and the potential risks to ecosystems and human health, Bangladesh should adopt a precautionary approach by progressively eliminating and ultimately prohibiting the intentional use of microplastics in toothpaste and other oral care products, rather than relying solely on permissible limits. **National regulatory standards, standardized testing methods, mandatory market surveillance, ingredient transparency, and certification requirements should be established to ensure that toothpaste products placed on the market are free from intentionally added microplastics.** These measures, together with strengthened laboratory capacity and the promotion of safer, sustainable alternatives, will be essential to protect public health, reduce plastic pollution, and safeguard aquatic ecosystems.

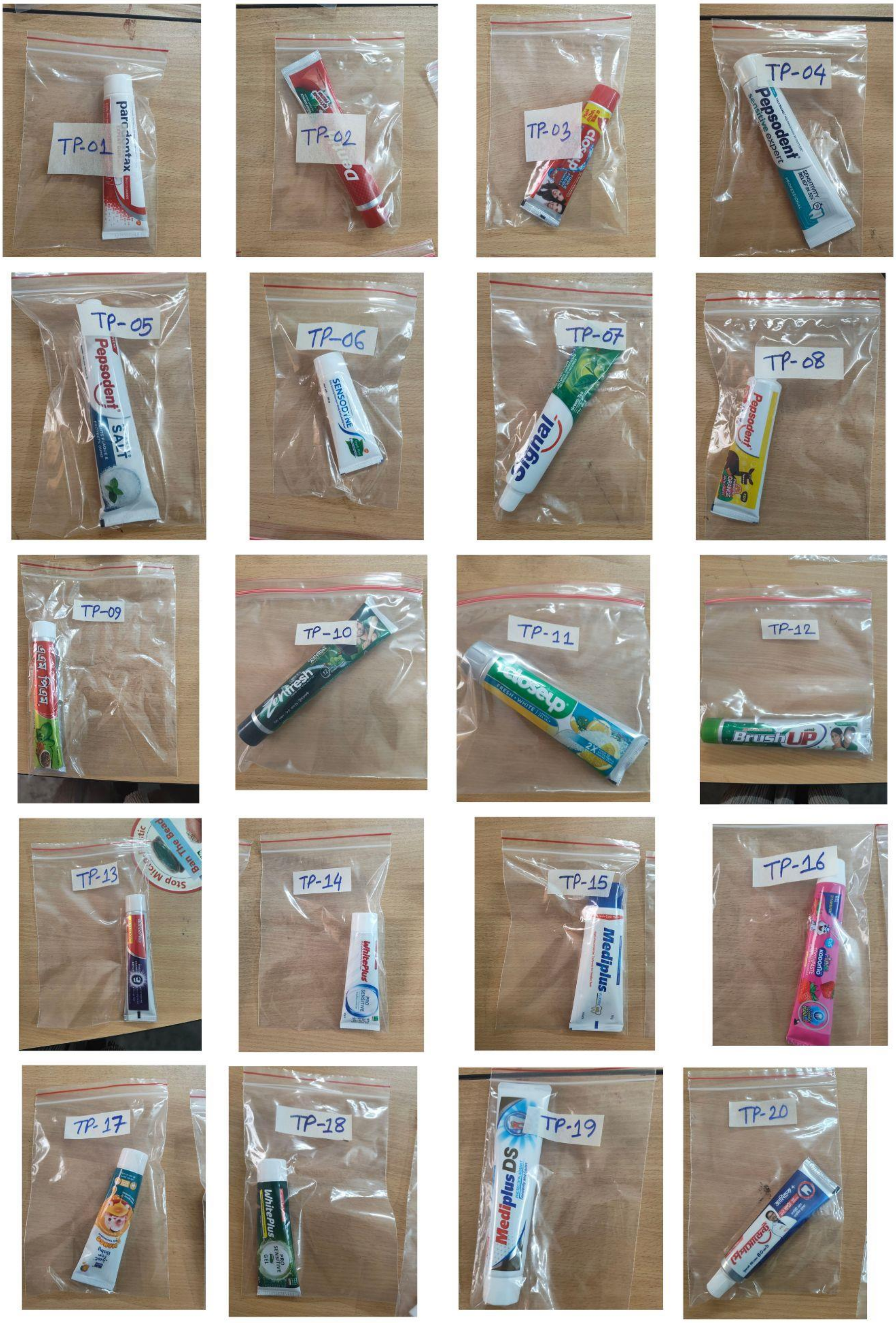
The findings of this study provide a strong scientific foundation for national policy development and support Bangladesh's transition toward microplastic-free oral care products, contributing to broader national and global commitments on plastic pollution reduction, environmental sustainability, and consumer safety.

10. Annex

Toothpaste Market Survey and Sample Collection



Toothpaste Samples Collected for Laboratory Analysis




TP-21
closeup


TP-22
Meril Baby

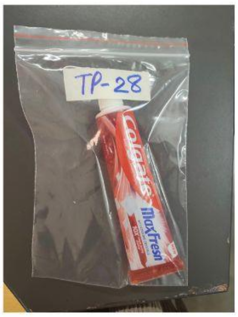

TP-23
Meril Baby


TP-24
ম্যাজিক

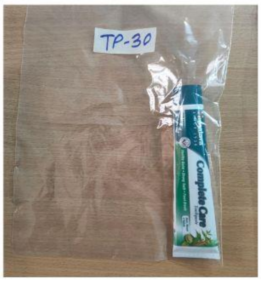

TP-25
MESWAK


TP-26
Signal


TP-27
SENSODYNE


TP-28
Colgate
MaxFresh


TP-29
closeup


TP-30
Complete Care

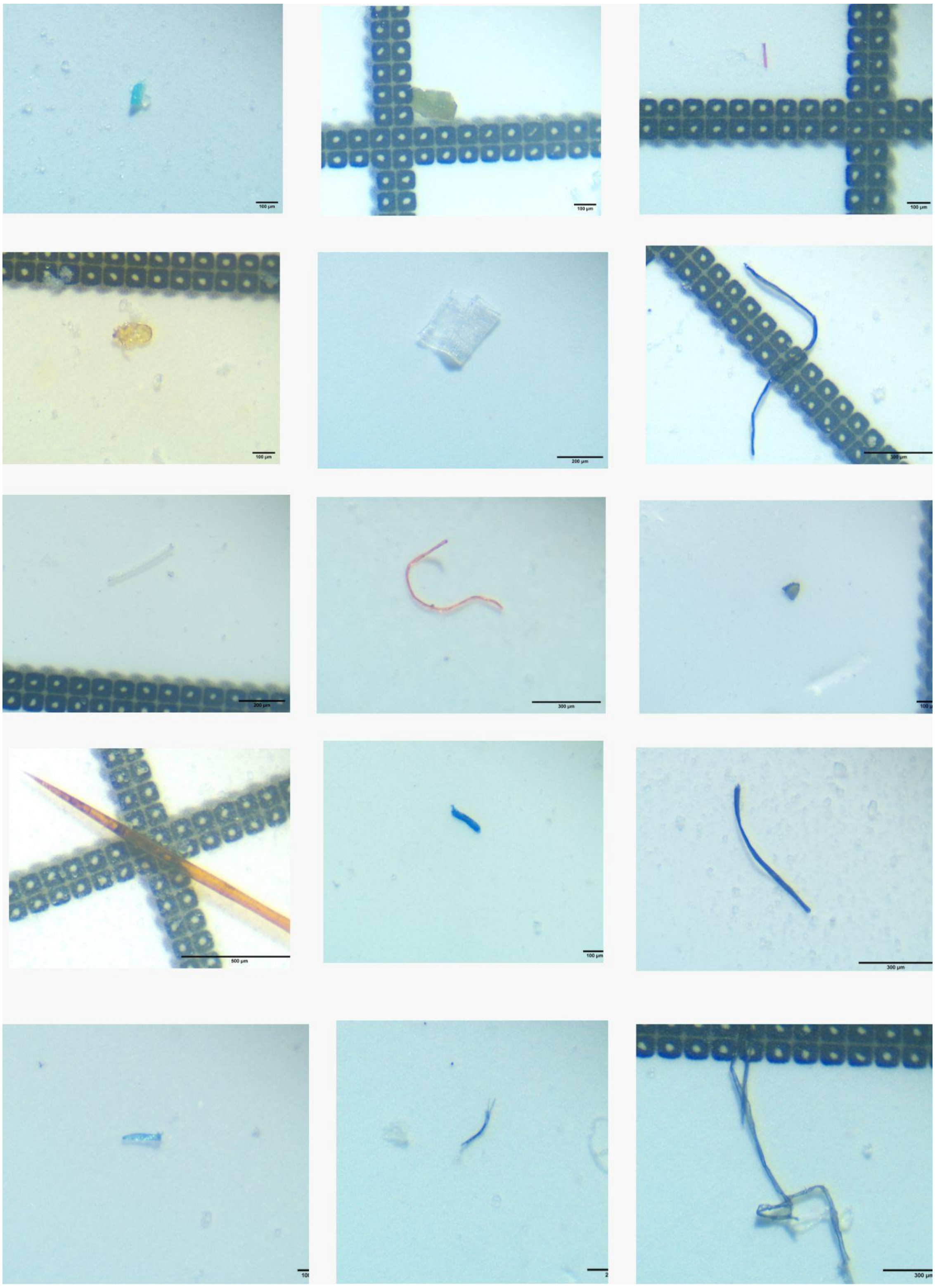

TP-31

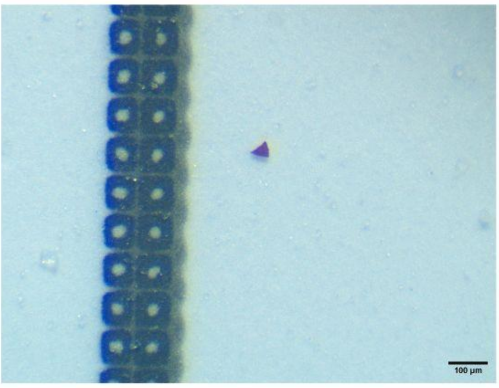

TP-32
Colgate
SALT

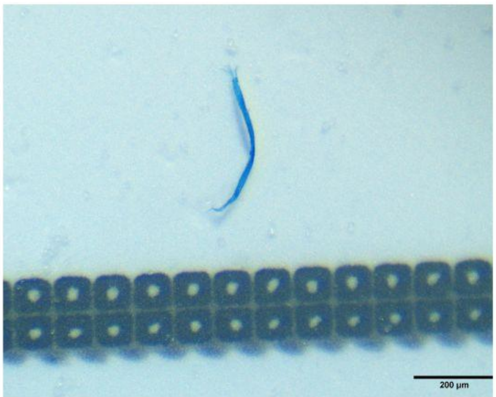

TP-33

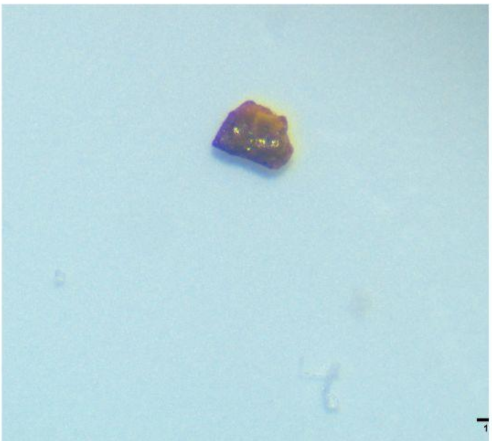

TP-34
closeup

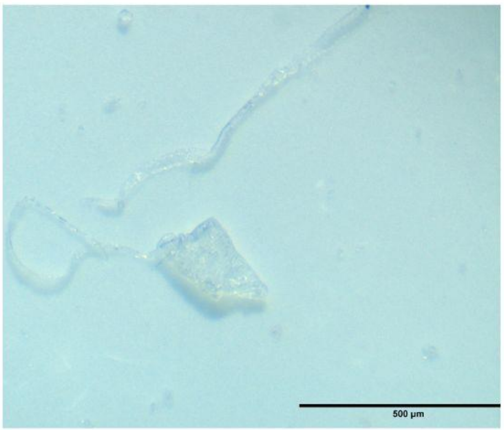
Representative stereomicroscopic images of microplastic particles isolated from available toothpaste sample




100 µm


200 µm

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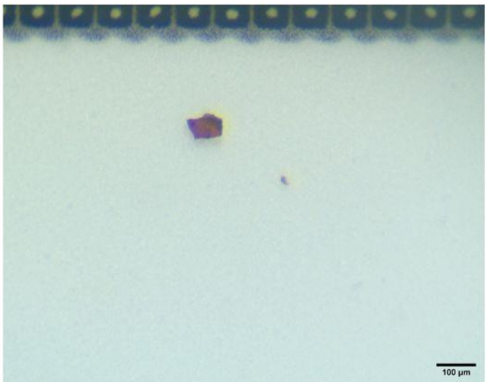
200 µm


100 µm


300 µm


500 µm

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