

Review

Microplastic Pollution in the Urban Water Cycle: A Comprehensive Review

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Abstract

Microplastic contamination in aquatic systems in urban areas is a cause for concern due to its ability to move from one location to another. This review investigates microplastic levels across different aquatic environments and its potential transport through the urban water cycle. This study explores current research on the presence and pathways of microplastics movement within the water cycle. It includes a comprehensive bibliometric analysis that identifies publication trends, dominant research themes, influential journals, and leading contributing countries. It covers microplastic occurrence across various natural environments, including marine, river, lake, and groundwater systems, and extends into the built environment such as water treatment facilities, wastewater systems, bottled water, and drinking water distribution networks. Results indicate that microplastic levels vary within the urban water cycle, with concentrations differing widely depending on geography, type of infrastructure, and sampling methodology. Despite some removal efficiency during treatment processes, residual microplastics remain prevalent in effluents and drinking water, posing potential ecological and health risks. This study identifies that some of the major challenges in determining the fate and transport of microplastics are inconsistent sampling methods, lack of standardization, and limited understanding of long-term impacts. This paper also identifies the necessity of coordinated global strategies that integrate policy, technology, and public awareness to mitigate microplastic contamination in urban water systems.



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1. Introduction

In 1972, E. J. Carpenter and K. L. Smith Jr. were the first researchers to report plastic pollution on the surface of the Sargasso Sea in the North Atlantic Ocean region [1]. Their study marked the beginning of scientific inquiry into plastic pollution, and their prediction that increasing plastic production would escalate marine plastic concentration has been repeatedly validated over the years [2–4]. Subsequently, microplastics (MPs) have drawn

worldwide attention, particularly following the publication of the first detailed report on the formation of “garbage patches” in gyres of oceans [5]. These studies indicate that the issue of microplastic pollution is increasing day by day in the marine environment, leading researchers to explore it further beyond marine systems into freshwater, terrestrial, and urban contexts [6–10].

The most frequently used plastics are polyethylene terephthalate (PET), polypropylene (PP), polyvinyl chloride (PVC), polyethylene (PE), both high-density and low-density, and polystyrene (PS) [9,11]. Altogether, these plastics account for around 90% of global plastic production. All these materials are utilized in various processes and products over a wide range of applications. However, plastic has a serious downside in that it can take decades to degrade completely, leading to long-term accumulation in the environment [10].

Due to prolonged persistence and fragmentation, they break down into smaller particles which are now present across all environmental media. Plastic particles in the environment can be subdivided based on particle size into four categories: macro-, meso-, micro-, and nanoplastics, as explained in Figure 1 [12,13]. Among the above-mentioned categories, micro- and nanoplastics are the most prevalent in the environment owing to their small particle size. Further, microplastics can exist as primary or secondary, depending on the source. Primary microplastics directly enter the environment in the form of microbeads, fibers, capsules, and pellets from different sources such as personal care products and industrial processes, while secondary microplastics are generated through the weathering of larger plastic particles by physical or chemical interaction with the environment [14,15].

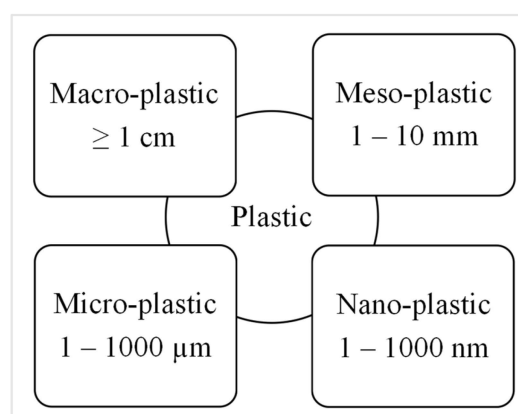


Figure 1. Categories of plastic in the environment.

The urban water cycle (UWC) can be defined as the movement of water within an urban ecosystem. This includes the collection, treatment, use, and disposal of water within cities. It involves the movement of water between natural and built environments. This enhances the potential for enhanced microplastic mobility. Owing to their ubiquitous nature and small size, microplastics are now considered intrinsic components of the UWC, as illustrated in Figure 2. As water circulates through urban infrastructure, microplastics migrate through various pathways, including natural water bodies, treatment systems, and distribution networks. However, our understanding of this microplastics movement across different phases of water remains limited due to insufficient research on their dynamic behavior in different urban systems [16].

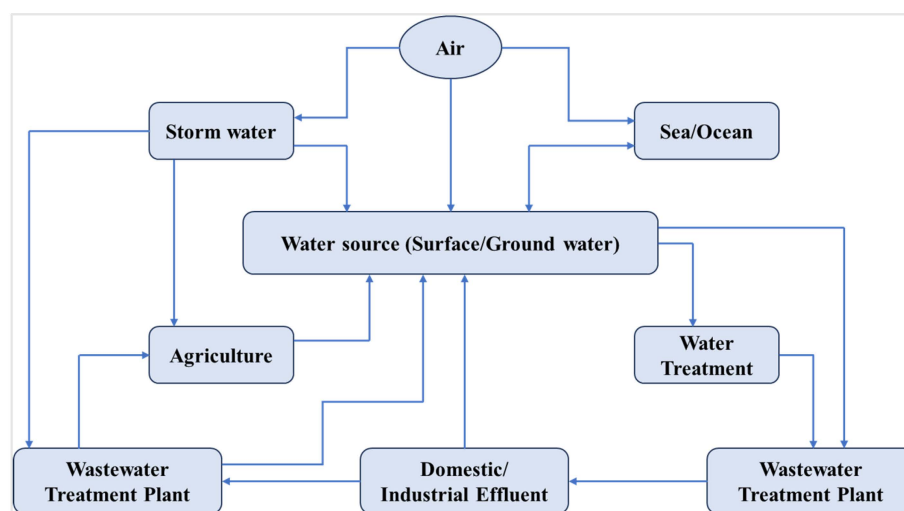


Figure 2. Microplastics movement in the urban water cycle.

Microplastics in the built environment present additional concerns related to human exposure [17]. In addition to aquatic environments, microplastics have also been detected within the atmosphere [18], thus increasing the likelihood of microplastics transport from the atmosphere to aquatic terrestrial environments. Land-based sources such as agricultural activities and waste disposal practices further increase the presence of microplastics in soils [19], with subsequent transport to aquatic environments via runoff and infiltration. Water and wastewater treatment plants are capable of removing some microplastics but also serve as potential sources, depending on their removal efficiency [20]. Moreover, plastic-based materials used in water distribution systems (like pipes and storage tanks) can act as secondary sources of contamination [21,22].

Several reviews have been published on microplastic contamination in marine and freshwater systems, focusing on environmental occurrence, sources, ecological impacts, and toxicological effects [9,23]. However, few studies have provided a comprehensive assessment of microplastics across the full UWC, including drinking water, wastewater treatment plants, distribution infrastructure, groundwater, and bottled water, as an interconnected and dynamic system. Existing studies tend to compartmentalize research into discrete domains, such as marine environments [12,24,25], riverine transport [26–28], or wastewater systems [29–32], without fully integrating the natural and built components of urban hydrology. There is an inherent lack of review articles investigating microplastic migration pathways within the UWC, in both natural and built environments. This is particularly critical as plastics have been predominantly in use within the urban environment and especially in the built environment.

Moreover, although bibliometric analyses on microplastic research have been conducted in broader environmental contexts [33–35], there is a lack of targeted bibliometric mapping that focuses specifically on urban water infrastructure. Considering the multidisciplinary and fragmented nature of microplastic studies, a bibliometric overview that reveals emerging themes, source networks, and research gaps can provide strategic direction for future investigations.

Accordingly, this study begins with a focused bibliometric analysis aimed at capturing the evolution of scientific interest in this domain. This analysis not only highlights publication trends and key thematic clusters but also provides the foundation for the literature synthesis that follows. By identifying the most active research areas and underexplored areas within the UWC, the bibliometric findings help inform and logically guide the comprehensive review of empirical studies presented in subsequent sections.

Thus, this review aims to provide a comprehensive assessment of microplastic contamination across the entire UWC, comprising of both natural elements (rivers, lakes, marine environments, groundwater) and built systems (drinking water networks, bottled water, wastewater treatment plants). Specifically, the objectives of this review are to:

1. Examine recent publication trends through a focused bibliometric analysis of microplastics research in the UWC.
2. Review the current state of knowledge on the occurrence and distribution of microplastics across key components of the UWC as recognized from the bibliometric study.
3. Analyze the migration pathways and transformation mechanisms of microplastics within the natural and built environments of urban hydrological systems.
4. Propose strategic research and policy directions to mitigate microplastic contamination in urban environments.

By combining bibliometric insights with an in-depth literature synthesis, this review offers a unique contribution to the field by framing the UWC as a unified system of microplastic transport and exposure. This article makes a unique contribution through reviewing the existing literature and evaluating the probable migration pathways within the UWC.

2. Materials and Methods

This study adopts a dual approach combining bibliometric analysis and an integrated literature review to assess microplastic contamination across the UWC comprehensively. Each component is outlined below in detail to ensure methodological transparency and reproducibility.

2.1. Bibliometric Analysis

Initially, this study involved a bibliometric analysis to examine the research landscape on microplastics within the UWC using data sourced from the Scopus database. This bibliometric analysis was conducted in alignment with the Guidance List for the Reporting of Bibliometric Analyses (GLOBAL) proposed by Donthu et al. [36], ensuring transparency, reproducibility, and methodological rigor. A comprehensive search strategy was employed using the query: ("microplastic*" AND "marine*") OR ("microplastic*" AND "river") OR ("microplastic*" AND "lake*") OR ("microplastic*" AND "ground water*") OR ("microplastic*" AND "water supply system*") OR ("microplastic*" AND "tap water*") OR ("microplastic*" AND "bottle water*") OR ("microplastic*" AND "wastewater*") OR ("microplastic*" AND "sediment*") OR ("microplastic*" AND "freshwater*"), yielding an initial 15,201 documents. To focus on the recent and relevant literature, the time frame was restricted to publications from 2016 to 2024, narrowing the dataset to 14,968 documents. Although data collection was performed in mid-2025, publications indexed under 2025 were retained if already available in the database. Subsequent filtering was applied to retain only English-language peer-reviewed articles and exclude document types such as reviews, conference papers, and editorials, among other filters, resulting in a refined dataset of 5897 articles. Articles were classified as "peer-reviewed" based on Scopus metadata and publisher categorization. The final bibliographic metadata, such as titles, abstracts, keywords, authorship, and references, were exported and analyzed using VOSviewer to generate keyword co-occurrence maps, among others, which informed the thematic structure of the subsequent literature review.

2.2. Literature Analysis

A comprehensive literature review was conducted to synthesize existing knowledge on the presence and migration of microplastics within the UWC. This review aimed to

capture the breadth of research across diverse environmental realms within the UWC. In this study, the UWC is broadly classified into natural and built environments. In an urban environment, water with microplastics and other contaminants travel across the natural and built environment. For this reason, this review identified the occurrence and range of microplastic contamination in both natural and built environments.

To ensure thematic alignment and analytical coherence, the structure of this literature review was informed by the results of the bibliometric analysis. Specifically, the keyword co-occurrence mapping conducted using VOSviewer v1.6.19 revealed five dominant thematic clusters in the existing body of literature. These clusters, focusing on the detection and characterization of microplastics, marine and freshwater contamination, sources and removal in wastewater systems, and human exposure, served as the basis for organizing the subsequent literature synthesis. Thus, search terms for this section encompassed combinations such as “microplastic*” with “marine”, “river”, “lake”, “groundwater”, “wastewater”, “tap water”, and “bottled water”. This approach ensured that the review reflects both empirical breadth and the prevailing research directions identified in the scholarly discourse.

Furthermore, this review was restricted to articles published in English from 2016 onwards, reflecting the period of intensified scientific focus on microplastics and ensuring the inclusion of methodologically robust and contemporary studies. After an initial screening of titles and abstracts, full-text articles were assessed for relevance to the UWC. “Key studies” were identified (76 studies) based on empirical depth, methodological rigor, and relevance to specific components of the UWC. While not following a formal meta-analysis or PRISMA protocol, this review employed a transparent search process and critical appraisal of the included literature, incorporating several of its core elements. However, Figure 3 gives an approximate PRISMA flow diagram, to improve clarity.

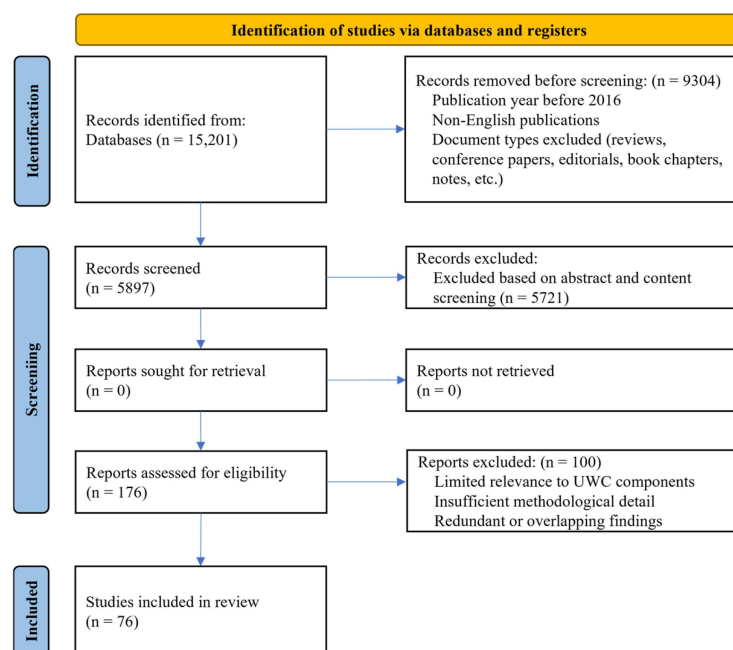


Figure 3. PRISMA flow diagram.

2.3. Integration and Synthesis

The resulting findings from both the bibliometric analysis and literature review were integrated and critically analyzed to identify dominant research themes, regional trends, methodological approaches, and knowledge gaps, forming the foundation for the thematic synthesis presented in subsequent sections.

Importantly, the in-depth literature analysis presented in Sections 4 and 5 also formed the basis for drawing broader conclusions regarding the distribution, transport mechanisms, and intervention points for microplastics within the UWC. Synthesized insights from this review informed the development of integrative visuals. These figures were designed to distill complex, multi-source findings into coherent frameworks that support strategic understanding and future mitigation planning.

Furthermore, insights from the thematic literature review also formed the foundation for the forward-looking challenges and research strategies discussed in Section 6.

3. Bibliometric Analysis

The following bibliometric analysis was conducted to identify dominant research trends, influential sources, and thematic clusters in the field of microplastic pollution in the urban water cycle. The insights gained from this analysis were subsequently used to structure the thematic focus of this literature review.

3.1. Annual Publications Analysis

The annual publication trend is shown in Figure 4. It shows a consistent and substantial rise in the number of publications from 2016 to 2024. The research output grew from just 49 publications in 2016 to a peak of 1426 publications in 2024, reflecting the growing academic and scientific interest in the field. Notably, the most rapid increases occurred after 2019, likely influenced by heightened global awareness and policy developments related to environmental sustainability and microplastic pollution. The sharp increase in research output after 2019 confirms the field's relevance and justifies the need for a comprehensive and up-to-date review. In some years, the number of publications increased by more than 50%, highlighting the strong and growing interest within the scientific community in microplastics-related research.

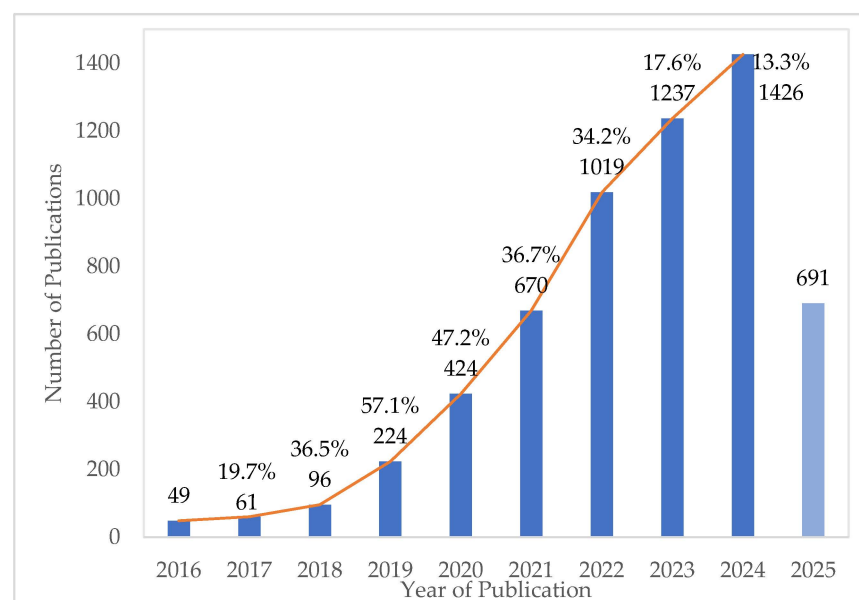


Figure 4. Annual number of publications showing a significantly increasing trend.

3.2. Co-Occurrence Analysis of All Keywords

The co-occurrence network, density, and overlay visualizations generated using VOSviewer reveal the evolving landscape of research on microplastic pollution in the UWC. The network diagram (Figure 5) highlights several major thematic clusters, with “microplastics” as the central node, frequently co-occurring with terms such as “plas-

[illegible]

<https://doi.org/10.3390/microplastics5010042>

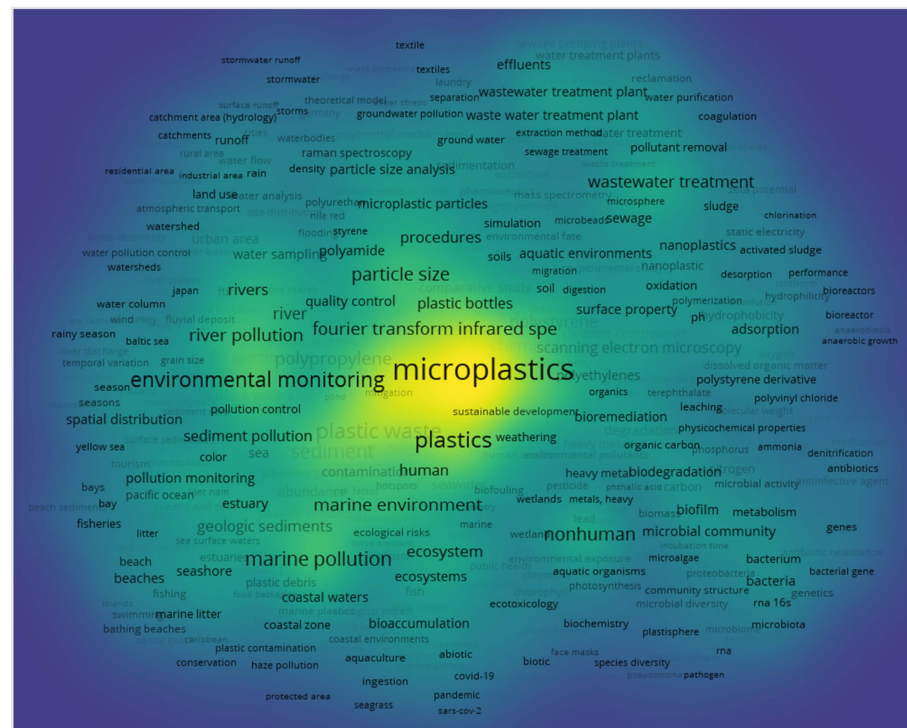


Figure 6. Co-occurrence of all keywords—Density Visualization (VOSviewer).

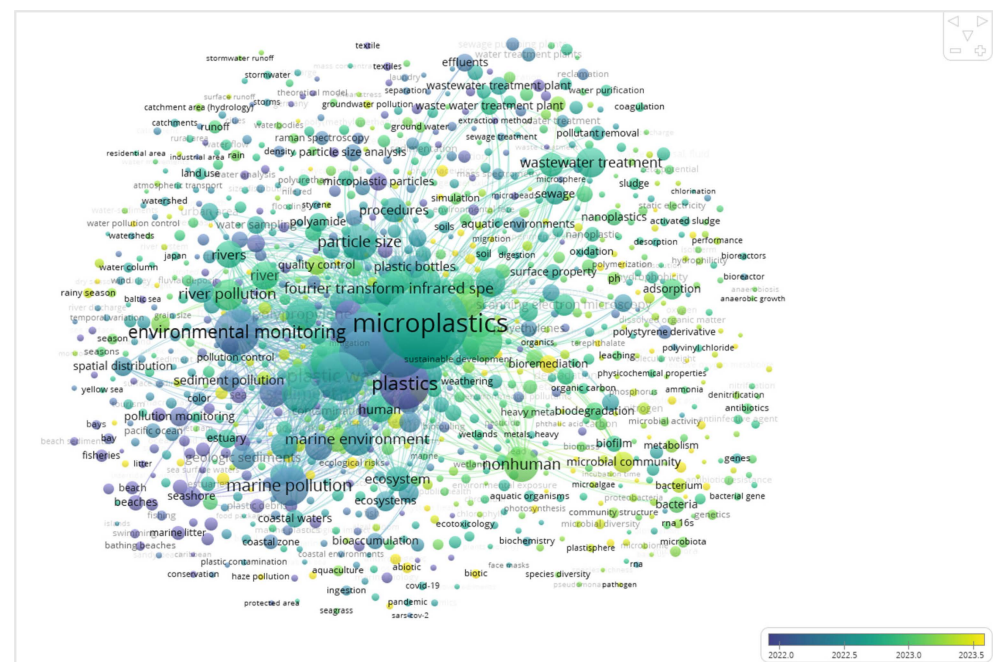


Figure 7. Co-occurrence of all keywords—Overlay Visualization (VOSviewer).

3.3. Citation and Bibliographic Coupling Analysis of Sources

Figure 8 highlights the top 15 journals (accounting for about 50% of all documents considered) contributing to the field based on the number of published documents, while Figure 9 shows the top 15 sources (accounting for about 65% of all citations) based on their citation counts. *Marine Pollution Bulletin* emerged as the most prolific source with the highest number of publications, followed by *Science of the Total Environment* and *Journal of Hazardous Materials*. These journals consistently publish a high volume of articles, suggesting their central role in disseminating research findings within environmental science and pollution-

related domains. Other notable contributors include *Water Research*, *Environmental Science and Pollution Research*, *Environmental Science & Technology*, and *Journal of Environmental Management*, reinforcing the multidisciplinary nature of the field.

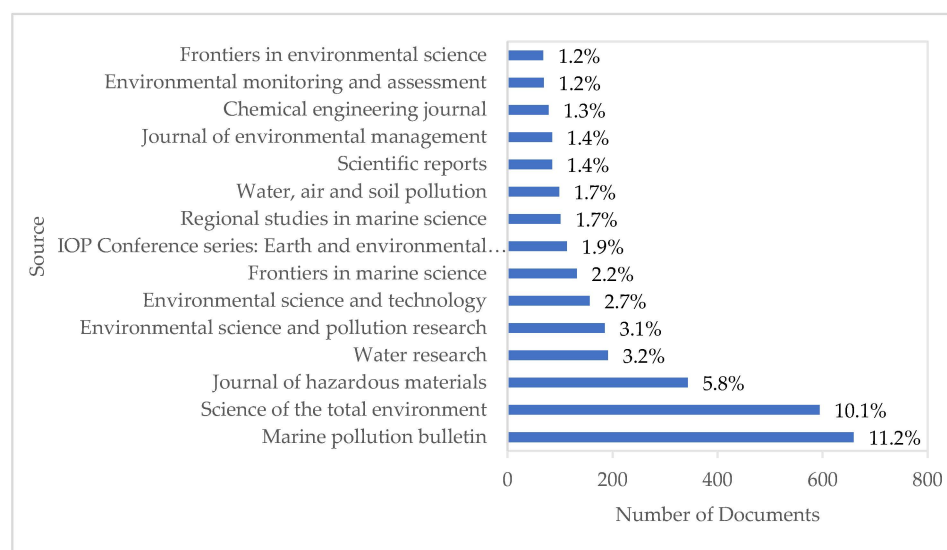


Figure 8. Top 15 sources based on number of documents.

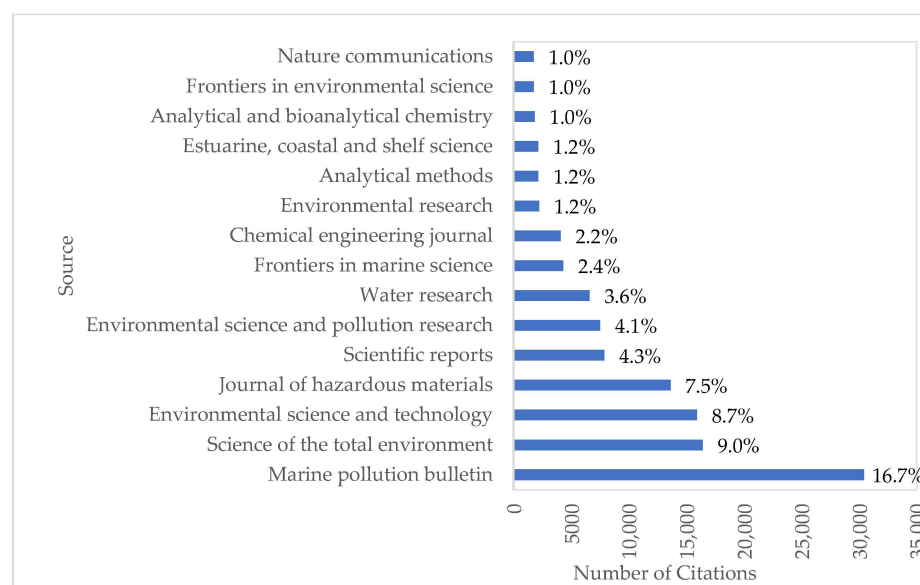


Figure 9. Top 15 sources based on number of citations.

Citation analysis revealed a similar trend, with *Marine Pollution Bulletin* also receiving the highest number of citations, exceeding 30,000, indicating its high impact and central role in advancing knowledge in this domain. *Science of the Total Environment* and *Environmental Science & Technology* follow as highly cited sources, reflecting their strong reputations and impacts. Journals such as *Journal of Hazardous Materials*, *Scientific Reports*, and *Environmental Science and Pollution Research* also demonstrate significant citation volumes, indicating that their contributions are widely recognized and referenced across the academic community.

Figure 10 illustrates the bibliographic coupling network of sources, highlighting the intellectual interconnectedness among core journals in the field. *Marine Pollution Bulletin* appears as the most central and strongly connected source, reaffirming its dominance identified in Figures 8 and 9 in terms of both publication volume and citation impact. Closely linked journals such as *Science of the Total Environment*, *Water Research*, and *Environmental*

Science and Pollution Research also occupy central positions, indicating their integral role in shaping interdisciplinary research related to environmental science and pollution. The network reveals distinct clusters, with journals grouped based on shared reference patterns, reflecting thematic concentrations such as marine science, water and soil pollution, and environmental management. This coupling analysis underscores the collaborative and multidisciplinary nature of the field, where leading journals not only disseminate high-impact research but also share a common intellectual foundation, reinforcing their influence across interconnected domains.

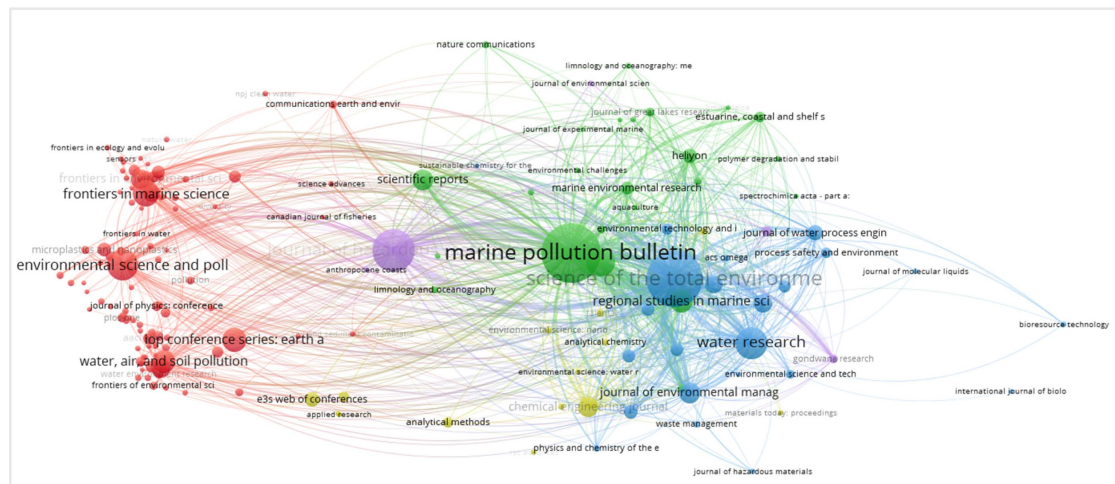


Figure 10. Bibliographic coupling of sources—Network Visualization (VOSviewer).

The prominence of journals focused on microplastic pollution helped identify which domains are most mature, guiding the prioritization of content in this review.

3.4. Citation and Bibliographic Coupling Analysis of Countries

Figures 11 and 12 collectively present a comprehensive overview of global research output and impact in the field. Figure 11 shows that China leads significantly in the number of documents published, followed by the United States, India, the United Kingdom, and Germany, highlighting a concentration of research productivity in both developed and emerging economies. The top 15 contributing countries accounted for approximately 94% of all documents in the dataset. It should be noted that these percentages are based on the full counting method used by default on VOSviewer, where each publication is attributed to all the affiliated countries of its authors. Consequently, multi-country collaborations may lead to minor overlaps in document counts across countries. Meanwhile, Figure 12 illustrates the distribution of citations, with China again at the forefront, indicating not only high output but also substantial influence. The United States and the United Kingdom also feature prominently in terms of citations, reflecting the sustained relevance and quality of their research. Notably, countries such as the Netherlands and Norway appear among the top 15 for citations despite not ranking high in publication volume, suggesting a high impact-to-output ratio. It should be emphasized here that the cumulative citation percentage exceeds 100% (in Figure 12) because VOSviewer applies the full counting method, as mentioned above. Consequently, papers co-authored across multiple countries are counted more than once; therefore, the cumulative citation percentages exceed 100%. This reflects collaborative contributions rather than mutually exclusive citation shares. Together, these figures underscore the dominant role of China and the U.S. in shaping the research landscape, while also highlighting the contributions of other countries whose works are garnering significant academic attention.

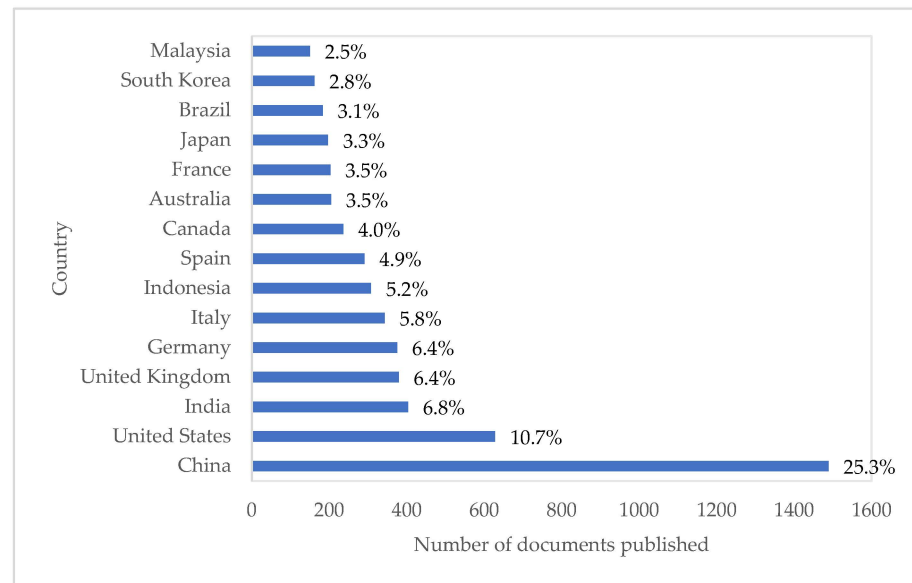


Figure 11. Top 15 countries based on the number of documents published.

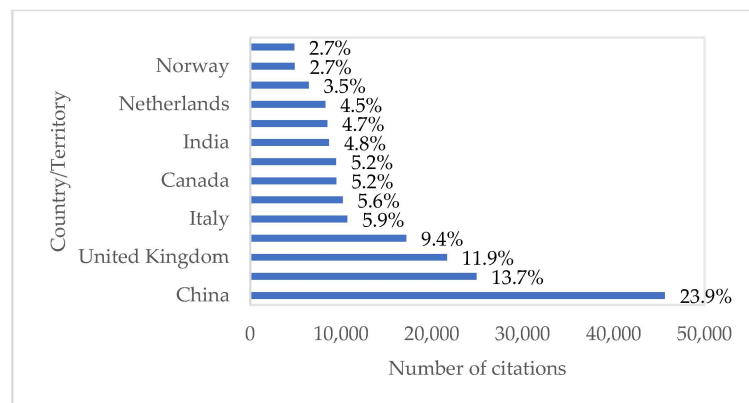


Figure 12. Top 15 countries based on the number of citations.

The bibliographic coupling network of countries (Figure 13) complements these findings by revealing the collaborative tendencies among nations based on shared citation patterns. China, the United States, Germany, the United Kingdom, and Italy emerge as central nodes, indicating their strong integration within the global research community and commonality in the referenced literature. China, in particular, demonstrates widespread coupling with both regional and international partners, reinforcing its dominant position not only in output and citations but also in collaborative influence. The network also highlights vibrant clusters of countries—such as those in Asia (e.g., India, Malaysia, Indonesia), Europe (e.g., Poland, Italy, Sweden), and the Americas (e.g., Brazil, Colombia)—illustrating thematic and regional affinities. The dense interlinkages across continents reflect a robust global research ecosystem in environmental science and pollution, driven by both high-output nations and emerging contributors. This reinforces the observation that impactful research in this field is increasingly shaped by interconnected, multidisciplinary, and cross-national collaborations.

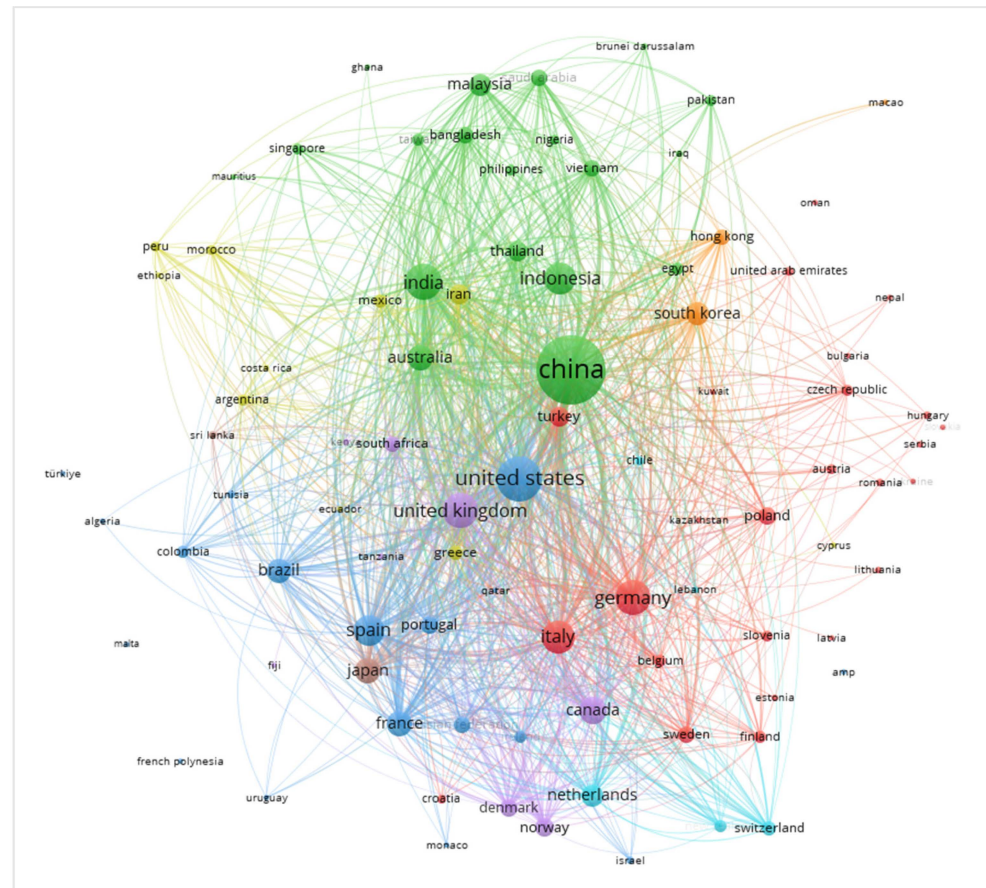


Figure 13. Bibliographic coupling of countries—Network Visualization (VOSviewer).

Overall, the bibliometric analysis highlights a rapidly expanding and increasingly interdisciplinary field, with research converging around key themes such as detection technologies, environmental monitoring, and microplastic behavior in freshwater and marine systems. The prominence of keywords related to rivers, lakes, wastewater, and urban infrastructure underscores the growing scientific interest in microplastic pollution across both natural and built environments. Thus, the bibliometric findings provided a map of the intellectual structure of research on microplastic pollution in the urban water cycle, identifying the most actively researched topics, influential contributors, and emerging focus areas. These insights were instrumental in shaping the thematic organization of the following literature review, ensuring it reflects both the current state and evolving directions of the field. However, while bibliometric mapping offers a macro-level overview of thematic evolution, it does not capture the detailed variability of microplastic contamination across specific water bodies. The following section, therefore, synthesizes findings from the recent literature focused on microplastic pollution in various water spheres, including marine, lake, groundwater systems, and others, to assess the scope and variability of contamination across diverse geographic and hydrological contexts.

4. Natural Environment

4.1. Marine

Microplastics are a pervasive contaminant in marine ecosystems, originating from various sources and accumulating in different environmental compartments. Studies on MPs in marine areas have been carried out in Asia, Oceania, North America, South America, Europe, and the Middle East. The presence of MPs has been reported in marine ecosystems such as bottom and beach sediments, open waters, and in organisms such as

fish and oysters. The effects of MPs on the marine environment and their interaction with the marine ecosystem are yet to be determined [24]. However, a wide variety of sample collection and identification methods have been applied by various researchers, as shown in the table below.

Zobkov and Esiukova [37] observed that fragments were present only near the coastline, while films primarily occurred farther from the shore. Fibers showed a different distribution pattern, with the highest concentration near the shore and an unsteady decrease moving offshore, likely due to variations in physical properties and near-bottom current velocities. Similarly, Halle et al. [38] reported a significant difference in microplastic abundance between large ($>1.2 \mu\text{m}$) and small particles in the North Atlantic Subtropical Gyre, with the latter reaching up to 7,000,000 pieces/ km^2 . In Hong Kong, Tsang et al. [25] found that microplastic concentrations in surface water varied widely, with values reaching up to 27,909 particles per 100 m^3 in highly urbanized regions. Akhbarizadeh et al. [39] detected up to 217 microplastic items per 200 g of dry coastal sediment near Khark Island, Iran, with fibers being the dominant type.

Dobaradaran et al. [40] highlighted significant contamination in the Persian Gulf, where microplastic abundance in beach sediments ranged from 618 to 25,453 items/ m^2 . In the Mediterranean, Baini et al. [41] found that microplastic density in Tuscany coastal waters reached 69,161.3 items/ km^2 at the surface, emphasizing the severity of pollution in the region. Zhu et al. [42] documented an average concentration of 545 microplastic items per cubic meter in seawater samples from the North Yellow Sea, a notably high value compared to sediment concentrations of 37.1 ± 42.7 items/kg.

Microplastics were also found in marine organisms. Zhu et al. [43] discovered that fish and oysters contained microplastics, with concentrations reaching up to 14.6 particles per gram of gastrointestinal tissue, raising concerns about bioaccumulation and food safety. In the northern Bering and Chukchi Seas, Mu et al. [44] reported microplastic concentrations of up to 68.78 items/kg in sediment, demonstrating that even remote polar regions are affected by microplastic pollution. In the North Atlantic, Poulain et al. [3] found that microplastic abundance varied significantly with size, with smaller particles ($<1 \text{ mm}$) reaching up to 14,000 particles/ km^2 .

Riverine contributions to marine pollution were evident in the East China Sea and Yangtze Delta, where Luo et al. [45] measured microplastic concentrations in surface water bodies ranging from 0.08 to 7.4 items/L. Meanwhile, Wang et al. [46] documented high levels of microplastic pollution in the South Yellow Sea, with sediment concentrations reaching 4205 particles/kg and benthic organisms containing between 1.7 and 47.0 particles/kg, suggesting potential impacts on marine food webs.

These findings underscore the widespread presence of microplastics in marine environments and their potential ecological implications. The variation in particle types, concentrations, and distribution patterns highlights the influence of local hydrodynamics, anthropogenic activities, and environmental factors on microplastic pollution. The following table (Table 1) summarizes studies that have investigated microplastic pollution in marine environments across different geographic locations.

Table 1. Investigation of microplastic pollution in marine environments across different geographic locations.

Site	Compartment(s) Studied	Sampling Methods	Identification Method	Unit	Particle * (μm)	MP	Reference
Baltic Sea	Bottom sediments	Rectangular hand-operated dredge	SM	Items/kg dry weight	≥ 20	-	[37]

Table 1. Cont.

Site	Compartment(s) Studied	Sampling Methods	Identification Method	Unit	Particle * (μm)	MP	Reference
North Atlantic Subtropical Gyre	Sea water	Manta trawl	ImageJ software, μ -FTIR, thermodesorption, thermochemolysis, Py-GCMS	Items/ km^2	≥ 1.2	Large MPs: 10,000–250,000 Small MPs: 500,000–7,000,000	[38]
Deep Bay, Tolo Harbor, Tsing Yi, and Victoria Harbor, Hong Kong	Surface water and sediment	Plankton net (153 μm), Ekman dredge	SM, ATR-FTIR	Items/100 m^3 (water), items/kg (sediment)	≥ 0.7	Water: 51–27,909 Sediment: 49–279	[25]
Khark Island, Iran	Coastal sediments	Grab sample	Binocular microscope, SEM-EDX	Items/200 g dry sediment	≥ 63	59–217	[39]
Persian Gulf Bushehr, Iran	Beach sediments	Grab sample	Epifluorescence microscope	Items/ m^2	≥ 2.5	618–25,453	[40]
Bohai Sea, China	Sea water	Trawl net	FTIR	Items/ m^3	≥ 330	0.33 ± 0.34	[47]
Tuscany Coast, Italy	Water column and surface samples	Manta trawl	SM with a LED light	Items/ m^3 (water), items/ km^2 (surface)	≥ 200	-	[41]
Bohai Sea and the Yellow Sea China	Sediment	Stainless-steel box sampler	SM, μ -FTIR	Items/50 g dry sediment	≥ 1.0	2–17	[48]
North Yellow Sea	Surface seawater and sediment	Niskin hydrophore and Gray-O'Hara box corer	Optical microscope, FTIR	Items/ m^3 (surface), items/kg (dry sediments)	≥ 30	-	[42]
Maowei Sea, China	Sea water, fish and oysters	Stainless-steel sampler, Local fishermen: fish and oysters	SM, μ -FTIR	Items/L (water), items/g (tissue)	≥ 20	Water: 1.2–10.1, GIT: 0.2–14.6, Gills: 0.0–12.3	[43]
Northern Bering and Chukchi Seas	Surface sediments	Stainless-steel box corer	Light SM, μ -FTIR	Items/kg dry sediment	≥ 0.7	0–68.78	[44]
North Atlantic	Sea water	Mesh net (25 and 300 μm)	μ -FTIR	Items/ km^2	25–1000	1–5 mm: 50–1000, <1 mm: 4–14,000	[3]
East China Sea and Yangtze Delta area, China	Creeks, rivers, estuaries, and the sea	Metal pail	SM, μ -FTIR	Items/L	≥ 20	0.08–7.4	[45]
South Yellow Sea, China	Sediments and benthic organisms	Box corer: sediment, Agassiz trawl: benthic organisms	SM, FTIR, SEM	Items/kg (dry sediment) items/kg (organism)	≥ 0.45	Sediment: 560–4205 Organisms: 1.7–47.0	[46]
Dubai Beach, United Arab Emirates	Sediment	Grab sample	SM, SEM, FTIR	Items/kg dry weight	≥ 0.45	8.43–133.98	[49]
Dubai beaches, United Arab Emirates	Surf/swash zone surface water	Grab sample (glass beaker)	Microscope, spectrometer, FTIR, Sentinel-2 imagery	mg/L, items/L	≥ 0.45	0.324–0.633 mg/L, 5.30–7.85 items/L	[50]

* “Size range analyzed” either refers to the limit of detection or, if that is not mentioned, the pore size of filters used.

Microplastic concentrations vary across studies due to local environmental factors and discrepancies in sampling and analytical methods, the latter frequently being the primary source of inconsistency. Sampling methods, like the size of the trawl mesh, the depth of the sample, and the volume of the filtered sample, have a big effect on how well detection works. Coarse trawls ($\geq 300\ \mu\text{m}$) underestimate fine particles and fibers, while grab or filtration methods with smaller pore sizes ($\leq 50\ \mu\text{m}$) yield higher counts. Analytical identification techniques also add variability. FTIR spectroscopy can reliably find polymers that are $20\ \mu\text{m}$ or larger, but it misses smaller ones. Raman spectroscopy can find particles that are less than $10\ \mu\text{m}$, but it is affected by fluorescence. SEM-EDX can tell you about the shape and elemental makeup of particles, but it cannot tell you what type of polymer they are. Advanced imaging tools like LDIR and μ -FTIR mapping make automation and spatial coverage better, but they still have limits on detection and spectral resolution. These methodological discrepancies frequently surpass authentic regional or hydrodynamic variations, thereby complicating cross-study comparisons. Consequently, subsequent research must utilize standardized, size-specific protocols and explicitly delineate detection limits to enhance comparability among marine microplastic datasets.

4.2. River

Microplastics are widely distributed in freshwater systems, including rivers and sediments, yet research on their presence and impact remains less extensive compared to marine environments. In recent years, growing attention has been given to the role of rivers as major transport pathways for microplastics, carrying contaminants from urban, industrial, and agricultural sources into larger water bodies. The following table (Table 2) summarizes studies on microplastic pollution in river systems worldwide, providing details on sampling methods, identification techniques, size ranges, and abundance levels.

Several key findings emerge from these studies. Microplastics in rivers are mainly comprised of polyvinylchloride, polyester, and polyamide. Generally, there were greater quantities of plastic at a downwind site [51]. Lin et al. [27] reported that microplastic abundance was lowest at a site located far from the urban center of Guangzhou City, with fibers comprising 80.9% of the total microplastics, followed by fragments (18.9%) and films (2.2%). Rodrigues et al. [26] reported that polyethylene and polypropylene were the most common polymer types in the Antuã River in Portugal, with seasonal variations in microplastic concentrations. Higher abundances were recorded in October ($5.8\text{--}51.7\ \text{mg m}^{-3}$ or $71\text{--}1265\ \text{items m}^{-3}$) compared to March ($5\text{--}8.3\ \text{mg m}^{-3}$ or $58\text{--}193\ \text{items m}^{-3}$), likely influenced by seasonal shifts in flow velocity, suspended solids, and temperature.

In the Pearl River, Guangzhou [27], microplastic levels ranged from 379 to 7924 items/ m^3 in water and 80 to 9597 items/kg in sediment, highlighting a significant contamination burden in densely populated areas. Meanwhile, studies in Poland's Vistula and Rudawa Rivers Pivokonsky et al. [52] found no detectable microplastic contamination, suggesting spatial variability in pollution levels. Research in Shanghai's urban waterways, including the Yangtze Estuary Luo et al. [45], detected concentrations between 0.08 and 7.4 items/L, confirming the role of river systems in microplastic transport.

Differences in sampling and identification methods, as well as hydrological and land-use factors, can cause reported microplastic concentrations in river systems to vary. Research utilizing finer filtration or grab sampling typically indicates greater abundances compared to studies employing coarse nets or restricted volumes. Methodological differences significantly contribute to the observed variability, akin to the marine studies examined in Section 4.1. These ranges of concentrations are generally lower than those observed in the marine environment. This indicates that coastal/marine environments are

more susceptible to microplastic pollution than rivers. This could be due to the fact that coastal environments are more commonly visited by tourists, as opposed to rivers.

These findings highlight the variability in microplastic pollution across different river systems, influenced by urbanization, hydrodynamics, and local environmental factors. Rivers serve as critical conduits for microplastics, underscoring the need for further research and targeted mitigation strategies.

Table 2. Investigation of microplastic pollution in rivers across different geographic locations.

Site	Compartment(s) Studied	Sampling Methods	Identification Method	Unit	Particle Size	MP	Reference
Great Lakes tributaries in six states, North America	River water	Manta trawl	Microscope	Particles/m ³	≥125 µm	0.05–32	[53]
River Thames basin, UK	Sediments	Stainless-steel scoop	Binocular light microscope, RS	Particles/100 g	1–4 mm	-	[28]
Antuã River, Portugal	Water and sediment	Mesh net: water, Van Veen grab: sediment	SM, ATR-FTIR	mg/m ³ or items/m ³ (water), mg/kg or items/kg (sediment)	0.055–5 mm	Water: 5–265 items/m ³ Sediment: 2.6–629 items/kg	[26]
Bloukrans River system, South Africa	Sediment	Quadrat	Microscope	Particles/kg	63–5000 µm	-	[54]
Pearl River, Guangzhou, China	Surface water and sediments	Water sampler, Van Veen grab	Light SM, µ-FTIR	Items/m ³ (water) and items/kg (sediment)	0.02–5 mm	Water: 379–7924 Sediment: 80–9597	[27]
Vistula and Rudawa River, Poland	River water	Direct samples in PP bottles	SM, SEM-EDX, DXR RS	Particles/5 L	≥0.4 µm	0	[55]
Shanghai city creeks, Suzhou River, Huangpu River, and Yangtze Estuary	Surface water	Air-lift pump from a boat	SM, µ-FTIR	Items/L	≥20 µm	0.08–7.4	[45]

4.3. Lakes

Microplastics have been detected in lakes worldwide, often influenced by urbanization, hydrological dynamics, and proximity to pollution sources. While research on microplastic contamination in marine and riverine systems has received significant attention, studies on lakes remain relatively limited. Lakes can serve as both temporary sinks and long-term reservoirs for microplastics, with contamination levels varying due to local environmental factors, inflowing riverine inputs, and anthropogenic activities. The following table (Table 3) summarizes key studies on microplastic pollution in lakes, detailing sampling methods, identification techniques, size ranges, and abundance levels.

Several notable trends emerge from these studies. In the Three Gorges Reservoir (TGR), China [56], microplastic concentrations in surface waters exhibited a spatial increase as the river flowed from rural areas toward the urban center, indicating a correlation between pollution levels and proximity to urbanization. Similarly, Dongting Lake and Hong

Lake in China [57] had microplastic concentrations ranging from 900 to 4650 particles/m³, with Hong Lake showing significantly higher contamination levels. In Qinghai Lake [58], surface water microplastic concentrations reached up to 7.58×10^5 items/km², with inflowing rivers also contributing microplastics, highlighting lakes' role as receivers of upstream pollution.

Inconsistencies in methodology can also cause differences in microplastic levels between lake studies. These differences can be due to local hydrodynamic and catchment characteristics. Changes in mesh size, sampling depth, and analytical resolution (like FTIR vs. visual microscopy) affect the rates of detection and the size distributions of particles. For reliable cross-lake comparisons, protocols that are consistent and specific to size are needed. The range of microplastic concentrations is lower than that in the marine environment and higher than those in rivers. This is understandable, as closed water bodies in lakes can accumulate microplastics more than rivers. Also, lakes in some locations have been used as tourist spots, though not as commonly as with coastal environments.

Table 3. Investigation of microplastic pollution in lakes across different geographic locations.

Site	Compartment(s) Studied	Sampling Methods	Identification Method	Unit	Particle Size	MP	Reference
Northern Tibet	Shore sediments	Quadrats and shovel	RS, SEM	Items/m ²	≥1.2 µm	8 ± 14 to 563 ± 1219	[59]
Taihu Lake, China	Plankton, surface water, sediments, and bottom fauna	Nylon plankton net, Peterson sampler, Fauna trawl	SM µ-FTIR, SEM-EDX	Items/km ² (plankton net), items/L (surface water), items/kg dry weight (sediments), items/g wet weight (Asian clams)	≥5-µm (surface water) ≥100 µm (plankton net)	Plankton net: 0.01×10^6 – 6.8×10^6 Surface water: 3.4–25.8 Sediment: 11.0–234.6 Asian clams: 0.2–12.5	[60]
Lake Bolsena, Lake Chiusi, Italy	Sediment, surface waters	Manta trawls	Nile Red staining with UV-microscope, SEM	Particles/kg dry weight (sediment), particles/m ³ (surface water)	≥1.6 µm	Lake Bolsena: 0.82 to 4.42 Lake Chiusi: 2.68–3.36	[61]
Great Lakes, US	Lake water	Manta trawl	Microscope	Particles/m ³	≥0.355 mm	0.05–32	[53]
Vembanad Lake, Kerala, India	Sediments	Van Veen grab	Compound microscope, µ-RS	Particles/m ²	<5 mm	96–496	[62]
Edgbaston Pool, Birmingham, UK	Sediments	HTH gravity corer	Binocular microscope	Particles/100 g dried sediment	≥500 µm	0–26	[63]
Three Gorges Reservoir, China	Sediment, surface waters	Van Veen grab	Dissecting microscope, µ-RS, SEM	Particles/m ³ (surface water), particles/kg wet weight (sediment)	≥48 µm	Surface water: 1597–12,611 Sediment: 25–300	[56]
Dongting Lake and Hong Lake, China	Surface waters	Stainless-steel sieve	Dissecting microscope, µ-RS, SEM	Particles/m ³	≥50-µm	Dongting Lake: 900–2800 Hong Lake: 1250–4650	[57]

Table 3. Cont.

Site	Compartment(s) Studied	Sampling Methods	Identification Method	Unit	Particle Size	MP	Reference
Qinghai Lake, China	Surface water, inflowing river waters, shore sediment, fish	Trawl net, quadrat with a stainless-steel shovel	SM, RS	Items/km ² (surface water), items/m ² (lakeshore sediment), and items/fish samples	≥0.112 mm	Surface water: 0.05 × 10 ⁵ –7.58 × 10 ⁵ In-flowing rivers: 0.03 × 10 ⁵ –0.31 × 10 ⁵ Shore sediment: 50–1292 Fish: 2–15	[58]
Lake Maggiore, Iseo and Garda in Italy	Surface water	Manta trawl	FTIR	Particles/km ²	≥300 µm		[64]
Western Lake Superior	Surface water	Manta trawl	Microscope, Pyr-GCMS, FTIR	Particles/km ²	≥80 µm	0–76,000	[65]
Poyang Lake, China	Surface water, sediments and fish	Steel sampler, stainless-steel sieve, Van Veen grab	SM, µ-RS	Items/L (surface waters), items/kg (sediments), and items/fish	≥0.45-µm	Surface water: 5–34 Sediment: 54–506 Wild Crucians: 0–18	[66]

In a study on European lakes, Sighicelli et al. [64] and others detected microplastic concentrations between 25,000 and 40,000 particles/km² in Lake Maggiore, Iseo, and Garda, underscoring significant contamination levels. Fischer et al. [61] reported sediment microplastic concentrations of up to 234 particles/kg in Lake Chiusi, Italy, with lower values observed in Lake Bolsena. Meanwhile, Vaughan et al. [63] identified microplastics in Edgbaston Pool, UK, with concentrations reaching 26 particles per 100 g of dried sediment.

In North America, microplastic contamination was documented in the Great Lakes, by Baldwin et al. [53], detecting concentrations ranging from 0.05 to 32 particles/m³. Western Lake Superior [65] exhibited variable microplastic densities, ranging from 0 to 76,000 particles/km², with an average of 37,000 particles/km².

These findings illustrate that lakes are significant microplastic repositories, influenced by urbanization, hydrology, and catchment characteristics. The variation in microplastic distribution highlights the need for further research to understand lakes' role in the transport, retention, and ecological impact of microplastic pollution.

4.4. Groundwater

Microplastic contamination in groundwater has received increasing attention in recent years, as studies have confirmed its presence even in deep aquifers. Unlike surface water systems, where microplastic pollution is often attributed to direct inputs from urban and industrial sources, the mechanisms driving microplastic infiltration into groundwater are less understood. Possible pathways include percolation from surface water, leakage from wastewater and septic systems, and infiltration through fractures in karst and porous aquifers. The following table (Table 4) summarizes key studies on microplastic pollution in groundwater, detailing sampling methods, identification techniques, size ranges, and abundance levels.

The reported concentrations of microplastics in groundwater differ significantly, influenced by aquifer characteristics and methodological variables. The frequency of detection is greatly affected by the sampling volume, the size of the filtration pore, and the analytical sensitivity. As noted in Section 4.1., standardizing the methods for collecting and identifying data would make it easier to compare studies of subsurface environments.

Several important findings have emerged from groundwater studies. Panno et al. [67] reported that all detected microplastics in Illinois karst aquifers were fibers, with concentra-

tions ranging from 0 to 15.2 particles/L. In a study of UK aquifers, Johnson et al. [68] found that polyethylene (PE) and polyvinyl chloride (PVC) accounted for 59% of all detected microplastics, with PE consistently present in all sampled boreholes. Selvam et al. [69] observed that microplastic concentrations in groundwater (4.2 particles/L) were lower than those in surface water (7.8 particles/L), suggesting that aquifer filtration processes might reduce microplastic transport. However, their presence still indicates vulnerability to contamination from septic systems, sinkholes, and municipal sewage.

In Germany, Mintenig et al. [70] found microplastic concentrations ranging from 0 to 7 particles/m³ in wells at a depth of 30 m, while in Australia, Samandra et al. [71] detected significantly higher concentrations in groundwater monitoring bores, ranging from 16 to 97 particles/L, with a mean of 38 ± 8 particles/L. Ganesan et al. [72] identified microplastics in groundwater from multiple locations in Chennai, India, with concentrations between 4 and 7 particles/L.

These findings highlight that groundwater, once considered a relatively pristine source, is susceptible to microplastic contamination. The variability in observed concentrations suggests that aquifer type, land use, and human activities influence microplastic infiltration. The range of microplastic concentrations appearing in groundwater is considerably lower than other natural aquatic environments. This is understandable, as soil serves as a filter medium prior to any microplastic migration to groundwater. As filtration is known to be a very effective treatment technique for any particle, it is still surprising that microplastics exist in groundwater. Further research is needed to understand the transport mechanisms and potential risks to drinking water resources.

Table 4. Investigation of microplastic pollution in groundwater across different geographic locations.

Site	Compartment(s) Studied	Sampling Methods	Identification Method	Unit	Particle Size (µm)	MP	Reference
Holdorf, Germany	Wells	Stainless-steel cartridge filters (3 µm)	Light SM/manual counting	Particles/m ³	>20	0–7	[70]
Illinois, USA	Karst aquifers	HDPE bottles from tap	Dissecting microscope, Py-GCMS	Particles/L	≥0.45	0–15.2	[67]
UK	Chalk and sandstone aquifers	Stainless-steel filters (10 µm)	FTIR	Particles/m ³	≥25		[68]
Chennai, India	Pallikaranai, Kovur, Pallipattu water	-	Optical microscope, SEM/EDX, ATR-FTIR	Particles/L	≥0.45	4–7	[72]
Tamil Nadu, India	Wells and bore wells	Teflon pump (20 L) through a stainless-steel sieve (50 µm)	SM, µ-FT-IR	Particles/L	≥50	0–10.1	[69]
Victoria, Australia	Capped bores	Amber glass bottles	LDIR	Particles/L	≥5	16–97	[71]
Sharjah, UAE	Wells and boreholes	Glass bottles	Optical microscope	Particles/L	≥0.45	-	[73]

4.5. Microplastics in the Natural Hydrologic Cycle

The schematic diagram in Figure 14 illustrates the major components of the hydrologic cycle, annotated with representative microplastic concentrations (in pieces per liter, pcs/L) identified in various compartments based on the published literature. Microplastics

are shown to be present in key stages such as condensation (10.3 pcs/L), precipitation (3.704 pcs/L), infiltration (3.8 pcs/L), percolation (39.07 pcs/L), runoff (3.19 pcs/L), reservoirs (7.10 pcs/L), and lakes (1.4 pcs/L). Although concentrations in evaporation and transpiration are not well established, their inclusion in the diagram highlights potential atmospheric transport pathways. This figure emphasizes the pervasive nature of microplastic pollution and its integration into natural water cycling processes.

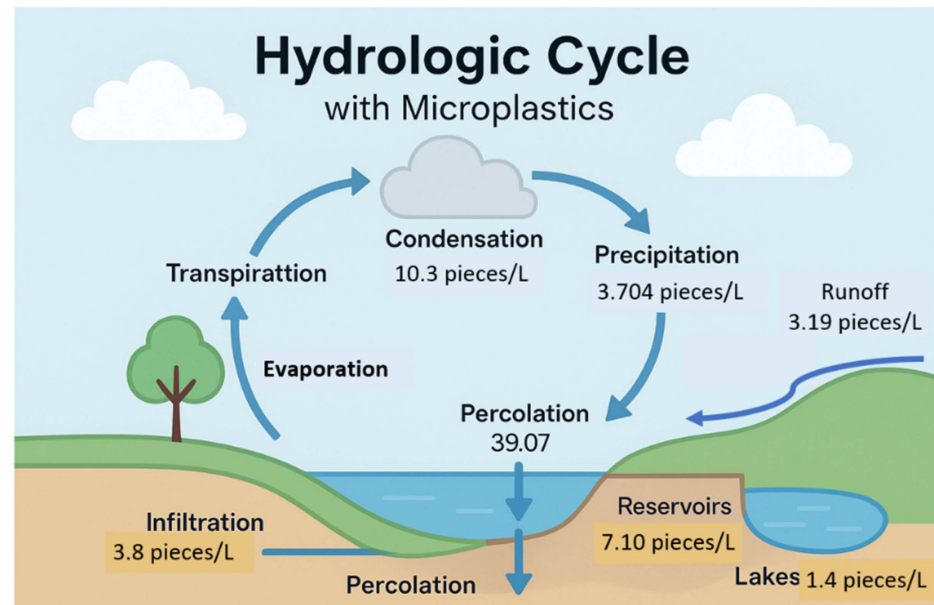


Figure 14. Hydrologic cycle with microplastic concentrations.

5. Built Environment

While the natural environment provides important insight into the fate and distribution of microplastics, the built environment plays an equally critical role in their generation, transformation, and transmission.

5.1. Water Supply System

Microplastic contamination in drinking water has become a growing concern, as studies have confirmed their presence in raw water sources, water treatment plant effluents, and tap water. While water treatment processes aim to remove contaminants, microplastics can still persist in treated water, and their presence in drinking water distribution networks raises questions about potential human exposure and health risks. The following table (Table 5) presents a summary of key studies on microplastic pollution in water supply systems (sampling methods, size, etc.).

Several notable findings have emerged from these studies. Pivokonsky et al. [52] reported that treated water in the Czech Republic contained up to 628 ± 28 particles/L, highlighting the persistence of microplastics despite treatment. Similarly, Wang et al. [74] found high concentrations (930 ± 72 particles/L) in an advanced drinking water treatment plant's (ADWTP) effluent in China, emphasizing that even sophisticated treatment processes may not fully eliminate microplastics. Kosuth et al. [75] conducted a global study of tap water and detected microplastics in multiple countries, with an average concentration of 5.45 particles/L.

Table 5. Investigation of microplastic pollution in water supply systems across different geographic locations.

Site	Compartment(s) Studied	Sampling Methods	Identification Method	Unit	Particle Size	MP	Reference
Czech Republic	Raw water, treated water	Borosilicate glass bottles	SEM, FTIR	Particles/L	$\geq 1 \mu\text{m}$	338 ± 76 to 628 ± 28	[52]
Germany	Inlet and outlet of WTP (treated by aeration and filtration)	Stainless-steel cartridge filters (3 μm)	Light SM/manual counting	Particles/ m^3	$>20 \mu\text{m}$	0–7	[70]
Cuba, Ecuador, England, France, Germany, India, Indonesia, Ireland, Italy, Lebanon, Slovakia, Switzerland, Uganda, US	Tap water	HDPE bottles	Stained with Rose Bengal (200 mg/L) dissection microscope	Particles/L	0.1–5 mm	0–61	[75]
China	Advanced drinking water treatment plant effluent	Brown glass bottles	SEM, μ -RS	Particles/L	$\geq 1 \mu\text{m}$	-	[74]
Sweden	WDN waterworks, pumping station, and corresponding hydrants	Stainless-steel filters (5 μm)	μ -FTIR, Py-GCMS	Particles/ m^3	8–374 μm $>6.6 \mu\text{m}$	0–1219	[76]
Mexico	Metro station drinking water fountain	Glass bottles	Epifluorescence microscope, manual counting	Particles/L	$\geq 0.22 \mu\text{m}$	5 ± 2 to 91 ± 14	[77]
Germany	House connections, transfer station, and consumption taps	Modified pressure filter housing	μ -RS	Particles/L	$\geq 10 \mu\text{m}$	0	[78]
England/Wales	Raw and potable water (WTPs sourcing water from lowland river, groundwater, and upland reservoir)	Metal filter holders containing woven or stainless-steel (10 μm pore size) filter	FTIR, MPhunter software program	Particles/L	$\geq 25 \mu\text{m}$	0.001–0.024	[68]
China	Tap water	HDPE bottle	Nile Red staining/fluorescence microscopy, μ -RS	Particles/L	$\geq 1 \mu\text{m}$	0–1247	[79]
China	DWTP, household tap, and pipe scales	Stainless-steel sieve (5 mm), glass bottles	SM, μ -FTIR	Particles/L, particles/kg (pipe scales)	$\geq 1 \mu\text{m}$	Tap water: 13.23 DWTP raw water: 134.79 Pipe scales: 569.99–751.73	[21]
Saudi Arabia	Tap water	Aluminum bottles	FTIR	Particles/L	25–500 μm		[80]
Denmark	Tap water (private households, private workplaces, private or public institutions)	Stainless-steel column mounted with a stainless-steel filter	SM, μ -FTIR	Particles/L	$>100 \mu\text{m}$	Max 30 MP in the 50 L sample found	[81]

Table 5. Cont.

Site	Compartment(s) Studied	Sampling Methods	Identification Method	Unit	Particle Size	MP	Reference
Hong Kong	Distilled waters, natural spring waters, mineral waters		Nile Red staining with fluorescence microscopy ($\geq 50 \mu\text{m}$) flow cytometry ($< 50 \mu\text{m}$)	Particles/L	$\geq 50 \mu\text{m}$ and $< 50 \mu\text{m}$		[82]
United Arab Emirates	Stagnant tap water	Water stagnated in PVC pipes (capped at both ends) for 5, 8.5 and 12 h	Dissecting microscope, ATR-FTIR, SEM-EDX	Particles/L	5–40 μm	-	[83]
Sharjah, United Arab Emirates	Water pumped through PVC, PE, PPR-based pipe loop network models (laboratory)	-	SM, FTIR	Particles (MP/NP count)	-	PVC: 12,317 PPR: 12,920 PE: 15,194	[84]

The broad spectrum of reported microplastic concentrations in drinking water indicates variations in treatment processes as well as in sampling and identification methodologies. Investigations employing finer filters and more sensitive analytical instruments (e.g., μFTIR or Raman spectroscopy) identify significantly greater quantities of particles compared to those utilizing visual or low-resolution methods. This shows how analytical resolution affects how comparable different water supply systems are.

Research in distribution networks has also provided insights into microplastic occurrence. Kirstein et al. [76] examined water distribution networks (WDNs) in Sweden and found microplastic concentrations ranging from 0 to 1219 particles/ m^3 , with significant variation between different pipelines. Similarly, Chu et al. [21] investigated microplastics in both drinking water and pipe scales in China, finding 13.23 particles/L in tap water but much higher concentrations (569.99–751.73 particles/kg) in pipe scale deposits, suggesting that aging infrastructure may serve as a secondary source of microplastics.

Regional studies have also shown variability in contamination levels. In Saudi Arabia, Almainan et al. [80] found relatively low microplastic concentrations in tap water (1.8 particles/L), whereas Tong et al. [79] reported higher values in China (440 ± 275 particles/L). In Denmark, Feld et al. [81] detected microplastics in tap water samples from 17 locations, with an average concentration of 0.31 ± 0.14 particles/L, while Weber et al. [78] reported no detectable microplastics in the drinking water of a German city.

Generally, WDNs should receive water from treatment plants. The mere presence of these microplastics indicates either current water treatment technologies are incapable of removing microplastics from water or the plastic in the WDN is contributing towards microplastic contamination. These findings highlight that while microplastic contamination in drinking water is a global issue, its prevalence varies significantly depending on water source, treatment efficiency, distribution infrastructure, and local environmental factors. Further research is necessary to understand the potential risks associated with long-term human exposure and to develop effective mitigation strategies within water supply systems.

5.2. Wastewater System (Sludge and Effluent)

Wastewater treatment plants (WWTPs) are both a source and a barrier to microplastic pollution, playing a crucial role in either mitigating or releasing microplastics into the environment. While treatment processes can remove a significant portion of microplastics

from influent water, substantial amounts may still be discharged in effluents or retained in sludge, which is often used in agriculture, potentially leading to secondary contamination. The following table (Table 6) summarizes key studies on microplastic pollution in wastewater systems, detailing influent, effluent, and sludge concentrations, as well as sampling and identification methods.

Several important findings emerge from these studies. Mason and his coworkers [85] reported microplastic concentrations in U.S. municipal WWTP effluents ranging from 0.004 to 0.195 particles/L, highlighting that even advanced treatment plants release microplastics. A secondary WWTP in Scotland [32] was able to remove most microplastics, yet 0.25 ± 0.04 particles/L may have remained in the effluent. In Germany, Mintenig et al. [86] observed a significant variation in effluent concentrations, ranging from 10 to 9050 particles/m³. Studies from Finland [87] showed that different treatment methods resulted in varying removal efficiencies, with membrane bioreactors (MBRs) achieving the highest reduction rates.

Table 6. Investigation of microplastic pollution in wastewater systems across different geographic locations.

Site	Compartment(s) Studied	Sampling Methods	Identification Method	Unit	Particle Size	MP Sludge	MP Influent	MP Effluent	Reference
United States	WWTP effluents	Extraction pump, Tyler sieves filtration	Dissection microscope	Particles/L	0.125–0.355 mm			0.004–0.195	[85]
Glasgow, Scotland	Secondary WWTP influent, effluent, and sludge	Steel buckets, steel sieve filtration	Dissection microscope, FTIR	Particles/L	$\geq 65 \mu\text{m}$		15.70 (± 5.23)	0.25 (± 0.04)	[32]
Netherlands	Municipal WWTP	Glass jars	Light microscope, FTIR	Particles/L (influent and effluent), particles/kg (sludge)	$\geq 10 \mu\text{m}$	510–760	68–910	51–81	[88]
Lower Saxony, Germany	WWTP effluents	Custom-made mobile pumping device	ATR-FTIR, μ -FTIR	Particles/m ³	$\geq 20 \mu\text{m}$			10–9050	[86]
Helsinki, Finland	Influent, after pretreatment, after the AS process, plant effluent, excess sludge, reject water, and dried sludge	Grab samples	SM, FTIR	Particles/L					[89]
Northern Italy	Inlet, after the settler, and outlet	Grab samples	μ -FTIR	Particles/L		113 $\pm$ 57	2.5 $\pm$ 0.3	0.4 $\pm$ 0.1	[90]
Finland	WWTP influent and effluent—after Filtration (F), DAF, and MBR	Custom-made filtering device with in situ fractionation	SM, FTIR	Particles/L (influent and effluent), MPs/g (sludge dry weight)	$\geq 20 \mu\text{m}$		DAF1: 0.5 $\pm$ 0.2 DAF2: 2 $\pm$ 1.3 F: 0.7 $\pm$ 0.1, 2 $\pm$ 0.07 MBR: 6.9 $\pm$ 1	0.3 $\pm$ 0.1 0.03 $\pm$ 0.01 0.02 $\pm$ 0.007 0.1 $\pm$ 0.04 0.005 $\pm$ 0.004	[87]
Finland	Influent water, after primary clarification and disinfection, permeation from MBR pilot plant and lake water from the nearby shore	Stainless-steel bucket attached to a metal wire and two sieves	Digital optical microscope, FTIR, μ -RS	Items/L, items/g dry weight	$\geq 250 \mu\text{m}$		57.6 $\pm$ 12.4	MBR: 0.4 CAS: 1 Overall: 1.05	[31]

Table 6. Cont.

Site	Compartment(s) Studied	Sampling Methods	Identification Method	Unit	Particle Size	MP Sludge	MP Influent	MP Effluent	Reference
China	WWTP sludge	Grab samples	SM, μ -FTIR	Particles/kg (dry sludge)	$\geq 37 \mu\text{m}$	$1.60\text{--}56.4 \times 10^3$	$227 \pm 121 \times 10^3$		[6]
Spain	Primary and secondary effluents, mixed sludge, processed heat-dried sludge	Grab samples	SM, μ -FTIR	Particles/L, particles/g (sludge)	$25 \mu\text{m}\text{--}50 \mu\text{m}$	183 ± 84 (mixed sludge) 165 ± 37 (heat-dried sludge)		12.8 ± 6.3	[91]
Morocco	Municipal wastewater treatment lagoon plant sludge	Grab samples	SM, Py-GCMS, Nile Red staining RS	Particles/kg dry matter	$\geq 0.45 \mu\text{m}$	Fresh sludge: $40.5 \pm 11.9 \times 10^3$ De-watered sludge: $36 \pm 9.7 \times 10^3$			[92]
Australia	Raw wastewater, de-gritted wastewater, waste AS, and UV-treated final effluent	Plastic buckets	Staining ATR-FTIR	Particles/L	$< 5 \mu\text{m}$	7.91 ± 0.44	11.80 ± 1.10	Wastewater: 5.23 ± 0.25 Waste AS: 7.91 ± 0.44 Effluent: 2.76 ± 0.11	[30]
China	WWTP sludge treated with 2-stage anaerobic digestion and dehydration	Shovel: dehydrated sludge collection	SM, Optical microscope, μ -FTIR	Particles/kg dry weight	$\geq 5 \mu\text{m}$	4044 ± 1359 (mean) $2933 \pm 611\text{--}5333 \pm 1501$			[93]
UK	WWTPs with AS, trickling filter, and biological aerated flooded filter with or without tertiary treatment	Composite samplers: influent and effluent, Glass Kilner jars using a metal trowel: sludge	μ -FTIR	Particles/L, particles/g dry weight	$\geq 25 \mu\text{m}$	$301\text{--}10,380$	$955\text{--}17,214$	$2\text{--}54$	[94]
Iran	WWTP sludge from the primary settling tank, clarifier, after sludge thickener, after aerobic digester, and mechanical de-watering unit	Metal shovels	SM, RS	Particles/g dry sludge	$\geq 37 \mu\text{m}$	Primary: 214 ± 16 Secondary: 206 ± 34 Thickening: 200 ± 13 Digestion: 238 ± 31 De-watered: 129 ± 17			[95]
China	WWTP influent, effluent, and sludge	Stainless-steel shovel: sludge	Optical microscope, FTIR	Items/L (influent and effluent), items/kg dry weight (sludge)	$\geq 0.45 \mu\text{m}$ (filter paper)	$234.7\text{--}6908.3$	$0.70\text{--}8.72$	$0.07\text{--}0.78$	[29]

The differences in the amount of microplastics in different wastewater treatment plants are partly due to differences in the way they treat wastewater and the quality of the influent, but they are also due to differences in the methods used. Using different pore sizes, digestion methods, and analytical tools (FTIR, Py-GCMS, SEM) has a big impact on how well recovery works and the concentrations that are reported. To get accurate results on how well microplastics are removed, the same analytical methods must be used every time.

Raw wastewater originates from human water use. The presence of plastic in an urban setting ensures that wastewater contains some level of microplastics. Sludge, a byproduct of wastewater treatment, has been found to contain high microplastic concentrations. Leslie et al. [88] detected 510–760 particles/kg in Dutch WWTP sludge, while Li et al. [6] found up to 56,400 particles/kg in China. Xu et al. [93] reported an average of

4044 ± 1359 particles/kg in sludge treated with anaerobic digestion, showing that sludge treatment does not eliminate microplastic contamination. In Spain, Edo et al. [91] found 165 ± 37 particles/g in heat-dried sludge, indicating potential risks if such sludge is applied as fertilizer. However, the presence of microplastics in the sludge indicates that existing wastewater treatment facilities are capable of removing some, if not all, microplastics from wastewater.

Effluent concentrations vary globally, with Magni et al. [90] detecting 0.4 ± 0.1 particles/L in Italy, while Zhang et al. [29] found 0.07–0.78 particles/L in China, demonstrating the effectiveness of treatment but also the persistence of microplastics. In Australia, Raju et al. [30] measured microplastic concentrations of 2.76 ± 0.11 particles/L in final effluents, showing that even secondary treatment cannot entirely remove them. This range of microplastics in the effluents are lower than most natural environments. This indicates that microplastics pollution in the natural environment is not entirely due to the treated wastewater discharge.

These findings emphasize the critical role of wastewater treatment plants in microplastic management. While they capture a significant portion of microplastics, the discharge of residual microplastics through effluent and sludge suggests a need for improved filtration technologies and stricter regulations to prevent environmental contamination.

5.3. Bottled Water System

The presence of microplastics in bottled water has become a major concern due to the potential for human exposure through daily consumption. Research suggests that factors such as plastic density, pH, and the quality of bottle material significantly influence contamination levels. Reusable plastic bottles have been found to contain higher microplastic concentrations than single-use bottles, likely due to repeated washing and mechanical stress [96]. Additionally, bottled water samples often contain microplastics from sources other than the bottle material, indicating contamination from water sources and manufacturing processes. The following table (Table 7) summarizes key studies on microplastic contamination in bottled water, including sampling methods, identification techniques, particle size ranges, and abundance levels.

Several important findings have emerged from these studies. Oßmann et al. [96] analyzed bottled mineral water in Germany and found that reusable PET bottles contained more microplastics (4889 ± 5432 particles/L) compared to single-use PET (2649 ± 2857 particles/L) and glass bottles (3074 ± 2531 particles/L). Similarly, Zuccarello et al. [97] reported high microplastic concentrations in Italian bottled water, with values ranging between 3.16×10^7 and 1.1×10^8 particles/L. Zhou et al. [98] detected 2–23 particles per bottle in China, while Almainan et al. [80] found lower contamination levels (1.9–4.7 particles/L) in Saudi Arabian bottled water.

Regional variations in microplastic contamination have also been observed. In Australia, Samandra et al. [99] found concentrations averaging 13 ± 19 particles/L, while Praveena et al. [100] reported 11.7 ± 4.6 particles/L in Malaysian bottled water. In Hong Kong, Tse et al. [82] found that microplastic concentrations in bottled water varied significantly based on particle size, with an average of 8–50 particles/L for larger microplastics (≥50 µm) and 1570–17,817 particles/L for smaller microplastics (<50 µm). The range of microplastic concentrations in bottled water is considerably high in some countries, creating a necessity for quality control in plastic bottle production and usage.

Studies have also focused on potential human exposure. Many researchers (like Li et al. 2024 [101]) have estimated microplastic ingestion based on daily water consumption. Given the wide range of reported contamination levels, further studies are necessary to

assess the long-term health risks associated with microplastic exposure through bottled water consumption.

It should also be noted here that the reported concentrations of microplastics in bottled water are significantly influenced by the sensitivity of the analytical method and the conditions of sampling. Research utilizing Nile Red staining succeeded by spectroscopic validation indicates elevated detection rates compared to methods relying exclusively on visual inspection. Differences in detection thresholds, bottle type, and analytical instruments (LDIR, Raman, FTIR) cause the differences between datasets that we see.

Table 7. Investigation of microplastic pollution in bottled water systems across different geographic locations.

Site	Compartment(s) Studied	Bottle Type	Identification Method	Unit	Particle Size	MP	MP (Mean)	Reference
Germany	Mineral water brands from Bavarian food stores	Single-use and reusable PET, single-use and reusable glass	μ -RS	Particles/L	$\geq 1 \mu\text{m}$		Single-use PET: 2649 $\pm$ 2857 Reusable PET: 4889 $\pm$ 5432 Glass: 3074 $\pm$ 2531	[96]
Italy	National brand sparkling and still waters	PET	SEM-EDX	Particles/L	0.5–10 μm	3.16107–1.1 $\times$ 108	5.42 $\times$ 107 $\pm$ 1.95 $\times$ 107	[97]
Chennai, India	Branded bottled water	-	Optical microscope, SEM-EDX, ATR-FTIR	Particles/L	$\geq 0.45 \mu\text{m}$	2–6		[72]
China	Local and international brands	PET	Focal plane array-based μ -FTIR	Particles/bottle (470–600 mL per bottle)	$\geq 25 \mu\text{m}$	2–23		[98]
Saudi Arabia	Local and international brands	Single-use PET, glass, hard PC	FTIR	Particles/L	25–500 μm		1.9–4.7	[80]
Iran	Different popular brands (Aquafina, Rijab, Kimia, Oxab, Vata, Damavand, Izmir, Vivant, Landa, Souwer, and Kohrang)	PET	Rose Bengal staining with SM, ATR-FTIR	Particles/L	$\geq 1.1 \mu\text{m}$	0–36	8.5 $\pm$ 10.2	[102]
Australia	Bottled water from commercial outlets (Australian-sourced, imported)	PET	LDIR imaging system, Agilent Clarity analysis software for identification	Particles/L	20 μm –500 μm	0–80	13 $\pm$ 19	[99]
Malaysia	Major brands bottled water (imported)	PET	Brightfield microscope, Image J software, FTIR	Particles/L	100–300 μm (0.45 μm filter used)	8–22	11.7 $\pm$ 4.6	[100]
Hong Kong	Different brands (distilled, natural spring, and mineral waters)	Single-use and reusable PET	Nile Red staining with fluorescence microscopy ($\geq 50 \mu\text{m}$), flow cytometry ($< 50 \mu\text{m}$)	Particles/L	$\geq 50 \mu\text{m}$ and $< 50 \mu\text{m}$		$\geq 50 \mu\text{m}$: 8–50 $< 50 \mu\text{m}$: 1570–17,817 Overall: 8955 $\pm$ 5205	[82]
India	Brands of natural mineral and packaged water	Single-use PET	Nile Red staining with fluorescence microscopy, ATR-FTIR	Particles/L	1 μm –5 mm 1–30 μm (detected range)	20 $\pm$ 5 to 127 $\pm$ 35		[103]
China	Different brands (local and foreign)	PET, glass	LDIR	Particles/L	$\geq 10 \mu\text{m}$	PET: 9.5–190.5 Glass: 4–168	72.32 $\pm$ 44.64	[101,104]

5.4. Microplastics in the Hydrologic Cycle in the Built Environment

The schematic (Figure 15) shows the flow of microplastics (MPs) through the urban water cycle, highlighting key sources, transformations, and pathways within the built environment. Surface water sources such as rivers, lakes, or reservoirs receive microplastics from the effluent of wastewater treatment plants and act as the initial input to water treatment plants. Although treatment processes (coagulation, sedimentation, filtration, and disinfection) reduce microplastic content, treated water still contains residual microplastics, with average concentrations reported as 290.69 particles/L/L. This water is supplied to households and industrial users, where additional microplastics are introduced through domestic activities (e.g., laundering synthetic textiles) and industrial processes.

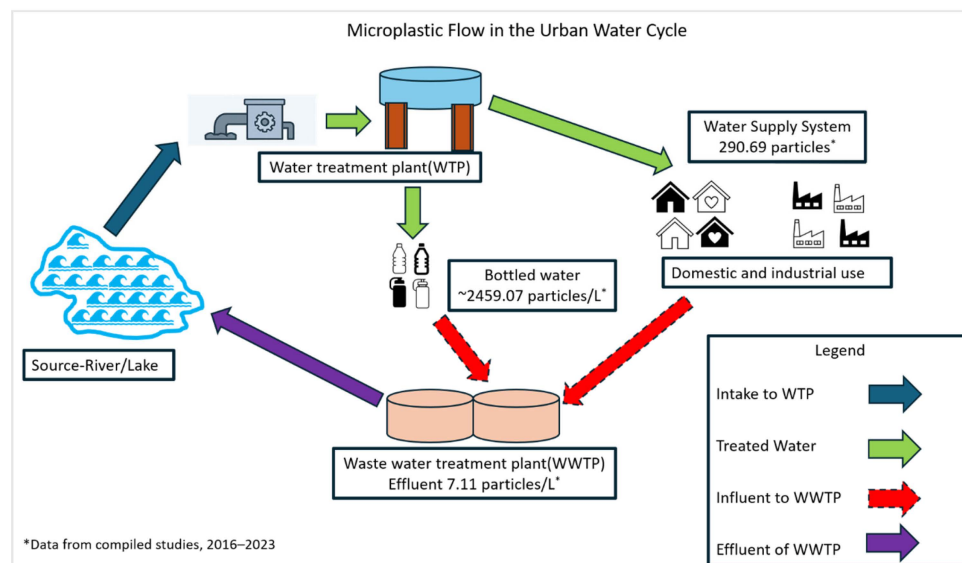


Figure 15. Microplastic pathways in the urban water cycle (built environment).

Water containing microplastics enters the wastewater treatment plant (WWTP), which consists of primary, secondary, and in some cases tertiary treatment stages. Despite these processes, effluent discharged back into natural water bodies contains an average of 7.11 particles/L. A significant portion of microplastics is retained in sewage sludge, which is often reused as fertilizer, potentially introducing microplastics into soil and groundwater systems. Bottled water, often derived from treated municipal or groundwater sources, also contributes to human microplastic exposure, with reported average concentrations of approximately 2459.07 particles/L.

The colored arrows indicate distinct flow types: blue for natural water movement, green for treated water supply, red dashed lines for influent to the wastewater plant, and purple for return flows from effluent discharge. The diagram emphasizes the persistence of microplastics across urban water infrastructure and underscores the need for improved filtration technologies and holistic management strategies.

The widespread presence of microplastics across water supply systems, wastewater infrastructure, and bottled water highlights the complexity of managing microplastic contamination in urban environments. Despite increasing documentation of microplastic occurrence in the built environment, questions remain about their long-term behavior, fate and transport, removal efficiency, and potential human health implications. Addressing these concerns requires not only technical solutions but also a deeper understanding of methodological limitations and regulatory gaps. The next section examines the key challenges facing microplastic research and outlines emerging strategies to mitigate pollution across the urban water cycle.

6. Research Strategies for Microplastic Pollution in the UWC

6.1. Challenges Facing Research

Despite increasing research on microplastic pollution, several challenges hinder comprehensive understanding and mitigation. The major concern arises from a lack of understanding of microplastics movement through different media. Within the UWC, water moves between liquid and gaseous phases. However, the mechanisms of microplastic movement are not quite clear. This originates from an ambiguity in the source detection of most microplastic pollution.

The reported microplastic concentrations exhibit significant variability across various elements of the urban water cycle, frequently attributable to methodological discrepancies rather than genuine environmental variations. Differences in sampling design, mesh or pore size, analytical resolution, and polymer identification methods (like FTIR, Raman, SEM, and LDIR) have a big impact on detection limits and how well studies can be compared. These differences show how important it is for microplastic research to have standardized protocols and harmonized analytical methods so that reliable assessments can be made across systems and regions.

Another major challenge lies in the under-recognition of diffuse and chronic sources of microplastics in the UWC. While most research has focused on fragmented particles from consumer products or industrial discharge, emerging evidence suggests that commercial plastic materials can act as continuous sources through leaching [14]. This finding underscores the need to account for passive leaching from infrastructure materials, packaging, and household plastics, which may significantly contribute to the overall microplastic load but remain largely unquantified in current monitoring frameworks.

Another key issue is the lack of standardized methodologies, with variations in sampling, detection techniques, and reporting making cross-study comparisons difficult. Size detection limitations further complicate research, as many studies fail to capture nanoplastics ($<1\ \mu\text{m}$), potentially underestimating contamination levels.

Environmental variability also poses challenges, as microplastic distribution is influenced by hydrodynamics, land use, and climate conditions, making it difficult to establish long-term trends. Identifying pollution sources remains complex due to the widespread use of plastics and their degradation into secondary microplastics.

The ecotoxicological and human health impacts of microplastics remain poorly understood, with limited research on their chronic effects and bioaccumulation risks. Additionally, policy and regulatory gaps persist, as existing measures primarily target microbeads while overlooking other major sources, such as synthetic textiles and tire wear particles.

Limited funding and research infrastructure in many regions further restrict large-scale monitoring and assessment efforts. Addressing these challenges requires international collaboration, standardized protocols, improved detection technologies, and increased regulatory oversight to better understand and control microplastic pollution in the urban water cycle.

6.2. Strategies to Address Microplastic Pollution

Effectively mitigating microplastic pollution requires a combination of research and development on improved understanding of microplastic movement, regulatory actions, technological advancements, and behavioral changes. Research initiatives are necessary to investigate the mobility, leachability, and movement of microplastic particles throughout the UWC. This can provide the foundation for developing control over microplastic pollution.

Strengthening regulations is crucial, including bans on primary microplastics, stricter emission controls for industries, and standardized monitoring protocols. Enhancing wastewater and drinking water treatment can further reduce microplastic discharge, with

advanced filtration methods like membrane bioreactors (MBRs), nanofiltration, and electro-coagulation showing promise.

Reducing microplastic release from consumer products is another key strategy. This includes promoting low-shedding textiles, washing machine filters, sustainable tire materials, and biodegradable packaging. Improving waste management through expanded recycling programs, landfill protections, and extended producer responsibility (EPR) policies can also help limit plastic pollution.

Public engagement is essential in raising awareness and encouraging sustainable habits, such as reducing single-use plastics, proper waste disposal, and supporting research initiatives. Given the complexity of microplastic pollution, a multi-sectoral approach involving policymakers, researchers, industries, and consumers is needed to implement effective mitigation strategies. By integrating these efforts, we can reduce microplastic contamination and its risks to water resources, ecosystems, and human health.

These strategies underscore the multifaceted nature of microplastic pollution management, setting the stage for a concise synthesis of key findings and priorities moving forward.

7. Conclusions

Microplastic pollution is a major environmental issue, contaminating water bodies, wastewater systems, and drinking water. Natural water bodies are the most studied environmental components, yet recent studies have also investigated the role of plastic usage within the built environment in contributing to the immobilization of microplastic particles. Common sources include textiles, tire wear, packaging, and wastewater effluents. While treatment plants are capable of removing some microplastics, effluents and sludge remain substantial contributors to environmental pollution. Tap and bottled water have also emerged as direct exposure pathways, raising concern over potential human health impacts.

This review identified a lack of integrated and system-wide studies, with most studies being isolated and focused on individual environmental compartments. There is an evident lack of coordinated investigations that consider microplastic movement at a watershed scale or throughout the entire urban hydrologic cycle. Improved understanding of microplastics movement and migration mechanisms across water, air, and land interfaces is required for designing effective mitigation strategies.

The bibliometric analysis revealed a steep rise in publications since 2016, peaking in 2024, signaling accelerating global interest in this field. Dominant publication and citation sources, such as *Marine Pollution Bulletin* and *Science of the Total Environment*, alongside keyword clusters, indicated a strong thematic focus on wastewater treatment, river pollution, and environmental monitoring. The overlay visualizations further showed a temporal research shift toward bioremediation, nanoplastics, and microbial interactions, suggesting a broadening of scope beyond occurrence and detection. China, the U.S., and several European countries lead the field in both research output and international collaborations. Despite this progress, urban-specific issues like stormwater pathways, aging infrastructure-related contamination, and atmospheric deposition are still underexplored.

These findings point to the need for more interdisciplinary and systems-level research that treats the UWC as a connected network rather than a collection of isolated components. Challenges remain, including a limited understanding of microplastic transport across the different environments within the UWC, a lack of standardized detection methods, and uncertain health risks. Current regulations focus narrowly on this field and often overlook widespread secondary sources. Effective strategies will require stronger policies, improved water treatment technologies, reduced upstream emissions, and better waste

management practices. Public awareness and sustainable practices also play a crucial role. A coordinated global effort is needed to mitigate microplastic pollution and protect ecosystems and human health.

In short, the in-depth integrative literature review presented in this study forms the basis for broader system-level insights into the distribution, transport, and intervention points of microplastics within the UWC. Synthesized findings from this review were used to inform the development of integrative visuals and conceptual frameworks aimed at supporting future planning, research coordination, and policy formation. Ultimately, tackling microplastic contamination will demand a collaborative and multi-sectoral approach that recognizes the UWC as both a conduit and a control point for this pervasive pollutant.

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Abbreviations

The following abbreviations are used in this manuscript:

MP	Microplastics
GIT	Gastrointestinal tracts
FTIR	Fourier-Transform Infrared Spectrometer
μ-FTIR	Micro-Fourier-Transform Infrared Spectrometer
ATR-FTIR	Attenuated Total Reflection Fourier-Transform Infrared Spectrometer
SM	Stereo-microscope
SEM	Scanning Electron Microscope
SEM-EDX	Scanning Electron Microscopy–Energy-Dispersive X-ray spectroscopy
GC-MS	Gas Chromatography–Mass Spectrometry
Py-GCMS	Pyrolysis-Gas Chromatography/Mass Spectrometry
RS	Raman Spectrometer
DXR-RS	Dynamic X-ray Raman Spectroscopy
μ-RS	Micro-Raman Spectroscopy
LDIR	Laser Direct Infrared Imaging
WDN	Water Distribution Network
WTP	Water Treatment Plant
DWTP	Drinking Water Treatment Plant
WWTP	Wastewater Treatment Plant

AS	Activated Sludge
CAS	Conventional Activated Sludge
MBR	Membrane Bioreactor
DAF	Dissolved Air Flotation
PET	Polyethylene Terephthalate
PC	Polycarbonate
PVC	Polyvinylchloride
PE	Polyethylene
PPR	Polypropylene
MP/NP	Microplastics/nanoplastics

References

1. Carpenter, E.J.; Smith, K.L. Plastics on the Sargasso sea surface. *Science* **1972**, *175*, 1240–1241. [[CrossRef](#)] [[PubMed](#)]
2. Foley, J. Reconstructing the First Record of Historical Microplastic Accumulation from Lake Sediments in Aotearoa New Zealand: A Case Study at Lake Wairarapa. Masters Thesis, Te Herenga Waka—Victoria University of Wellington, Wellington, New Zealand, 2025. [[CrossRef](#)]
3. Poulain, M.; Mercier, M.J.; Brach, L.; Martignac, M.; Routaboul, C.; Perez, E.; Desjean, M.C.; ter Halle, A. Small Microplastics As a Main Contributor to Plastic Mass Balance in the North Atlantic Subtropical Gyre. *Environ. Sci. Technol.* **2019**, *53*, 1157–1164. [[CrossRef](#)] [[PubMed](#)]
4. Eriksen, M.; Lebreton, L.C.M.; Carson, H.S.; Thiel, M.; Moore, C.J.; Borerro, J.C.; Galgani, F.; Ryan, P.G.; Reisser, J. Plastic Pollution in the World's Oceans: More than 5 Trillion Plastic Pieces Weighing over 250,000 Tons Afloat at Sea. *PLoS ONE* **2014**, *9*, e111913. [[CrossRef](#)] [[PubMed](#)]
5. Day, R.; Shaw, D.; Ignell, S. The Quantitative Distribution and Characteristics of Neuston Plastic in the North Pacific Ocean, 1985–88. In Proceedings of the Second International Conference on Marine Debris, Honolulu, HI, USA, 2–7 April 1989; pp. 247–263.
6. Li, X.; Chen, L.; Mei, Q.; Dong, B.; Dai, X.; Ding, G.; Zeng, E. Microplastics in sewage sludge from the wastewater treatment plants in China. *Water Res.* **2018**, *142*, 75–85. [[CrossRef](#)]
7. Rai, M.; Pant, G.; Pant, K.; Aloo, B.N.; Kumar, G.; Singh, H.B.; Tripathi, V. Microplastic Pollution in Terrestrial Ecosystems and Its Interaction with Other Soil Pollutants: A Potential Threat to Soil Ecosystem Sustainability. *Resources* **2023**, *12*, 67. [[CrossRef](#)]
8. Feizi, F.; Akhbarizadeh, R.; Hamidian, A.H. Microplastics in urban water systems, Tehran Metropolitan, Iran. *Environ. Monit. Assess.* **2024**, *196*, 643. [[CrossRef](#)]
9. Capodaglio, A.G. Microplastics in the urban water cycle: A critical analysis of issues and of possible (needed?) solutions. *Sci. Total Environ.* **2024**, *954*, 176580. [[CrossRef](#)]
10. Yousafzai, S.; Farid, M.; Zubair, M.; Naeem, N.; Zafar, W.; Farid, S.; Ali, S. Detection and degradation of microplastics in the environment: A review. *Environ. Sci. Adv.* **2025**, *4*, 1142–1165. [[CrossRef](#)]
11. Geyer, R.; Jambeck, J.R.; Law, K.L. Production, use, and fate of all plastics ever made. *Sci. Adv.* **2017**, *3*, e1700782. [[CrossRef](#)]
12. Cozar, A.; Echevarria, F.; Gonzalez-Gordillo, J.I.; Irigoien, X.; Ubeda, B.; Hernandez-Leon, S.; Palma, A.T.; Navarro, S.; Garcia-de-Lomas, J.; Ruiz, A.; et al. Plastic debris in the open ocean. *Proc. Natl. Acad. Sci. USA* **2014**, *111*, 10239–10244. [[CrossRef](#)]
13. Bermúdez, J.R.; Swarzenski, P.W. A microplastic size classification scheme aligned with universal plankton survey methods. *MethodsX* **2021**, *8*, 101516. [[CrossRef](#)] [[PubMed](#)]
14. Mortula, M.M.; Atabay, S.; Fattah, K.P.; Madbully, A. Leachability of microplastic from different plastic materials. *J. Environ. Manag.* **2021**, *294*, 112995. [[CrossRef](#)] [[PubMed](#)]
15. Wu, P.; Huang, J.; Zheng, Y.; Yang, Y.; Zhang, Y.; He, F.; Chen, H.; Quan, G.; Yan, J.; Li, T.; et al. Environmental occurrences, fate, and impacts of microplastics. *Ecotoxicol. Environ. Saf.* **2019**, *184*, 109612. [[CrossRef](#)] [[PubMed](#)]
16. Almeida, M.P.D.; Gaylarde, C.; Pompermayer, F.C.; Lima, L.D.S.; Delgado, J.D.F.; Scott, D.; Neves, C.V.; Vieira, K.S.; Neto, J.A.B.; Fonseca, E.M. The Complex Dynamics of Microplastic Migration through Different Aquatic Environments: Subsidies for a Better Understanding of Its Environmental Dispersion. *Microplastics* **2023**, *2*, 62–77. [[CrossRef](#)]
17. Prasittisopin, L.; Ferdous, W.; Kamchoom, V. Microplastics in construction and built environment. *Dev. Built Environ.* **2023**, *15*, 100188. [[CrossRef](#)]
18. Chaloupecká, H.; Suchánek, J.; Wild, J.; Mamula, M.; Kellnerová, R.; Nevrlý, V.; Dostál, M.; Zelinger, Z. Investigating the formation of microplastic aerosols and their dispersion in urban environments: A comparative physical modelling study of aerosol and gas dispersion. *Atmos. Pollut. Res.* **2025**, *16*, 102481. [[CrossRef](#)]
19. Seo, Y.; Chevali, V.; Lai, Y.; Zhou, Z.; Chen, G.; Burey, P.; Wang, S.; Song, P. Microplastics in soils: A comparative review on extraction, identification and quantification methods. *J. Environ. Manag.* **2025**, *377*, 124556. [[CrossRef](#)]

20. Cavazzoli, S.; Murari, F.; Donegà, M.; Tirler, W.; Andreottola, G. Microplastic removal and environmental emissions from municipal wastewater treatment plants. *J. Clean. Prod.* **2025**, *521*, 146267. [\[CrossRef\]](#)
21. Chu, X.; Zheng, B.; Li, Z.; Cai, C.; Peng, Z.; Zhao, P.; Tian, Y. Occurrence and distribution of microplastics in water supply systems: In water and pipe scales. *Sci. Total Environ.* **2022**, *803*, 150004. [\[CrossRef\]](#)
22. Chen, Y.; Wang, Y.; Hu, B.; Su, L. Drinking Water Network as a Potential Pathway for Micro- and Nanoplastics Exposure to Human: A Mini Review. *Water* **2025**, *17*, 1188. [\[CrossRef\]](#)
23. Li, J.; Liu, H.; Paul Chen, J. Microplastics in freshwater systems: A review on occurrence, environmental effects, and methods for microplastics detection. *Water Res.* **2018**, *137*, 362–374. [\[CrossRef\]](#)
24. Avio, C.G.; Gorbi, S. Plastics and microplastics in the oceans: From emerging pollutants to emerged threat. *Environ. Res.* **2017**, *128*, 2–11. [\[CrossRef\]](#) [\[PubMed\]](#)
25. Tsang, Y.; Mak, C.; Liebich, C.; Lam, S.; Sze, E.; Chan, K. Microplastic pollution in the marine waters and sediments of Hong Kong. *Mar. Pollut.* **2017**, *115*, 20–28. [\[CrossRef\]](#) [\[PubMed\]](#)
26. Rodrigues, M.; Abrantes, N.; Gonçalves, F.; Nogueira, H.; Marques, J.; Gonçalves, A. Spatial and temporal distribution of microplastics in water and sediments of a freshwater system (Antuã River, Portugal). *Sci. Total Environ.* **2018**, *633*, 1549–1559. [\[CrossRef\]](#) [\[PubMed\]](#)
27. Lin, L.; Zuo, L.-Z.; Peng, J.-P.; Cai, L.-Q.; Fok, L.; Yan, Y.; Li, H.-X.; Xu, X.-R. Occurrence and distribution of microplastics in an urban river: A case study in the Pearl River along Guangzhou City, China. *Sci. Total Environ.* **2018**, *644*, 375–381. [\[CrossRef\]](#)
28. Horton, A.; Svendsen, C.; Williams, R.; Spurgeon, D.; Lahive, E. Large microplastic particles in sediments of tributaries of the River Thames, UK—Abundance, sources and methods for effective quantification. *Mar. Pollut. Bull.* **2017**, *114*, 218–226. [\[CrossRef\]](#)
29. Zhang, L.; Liu, J.; Xie, Y.; Zhong, S.; Gao, P. Occurrence and removal of microplastics from wastewater treatment plants in a typical tourist city in China. *J. Clean. Prod.* **2021**, *291*, 125968. [\[CrossRef\]](#)
30. Raju, S.; Carbery, M.; Kuttykattil, A.; Senthirajah, K.; Lundmark, A.; Rogers, Z.; Scb, S.; Evans, G.; Palanisami, T. Improved methodology to determine the fate and transport of microplastics in a secondary wastewater treatment plant. *Water Res.* **2020**, *173*, 115549. [\[CrossRef\]](#)
31. Lares, M.; Ncibi, M.; Sillanpää, M.; Sillanpää, M. Occurrence, identification and removal of microplastic particles and fibers in conventional activated sludge process and advanced MBR technology. *Water Res.* **2018**, *133*, 236–246. [\[CrossRef\]](#)
32. Murphy, F.; Ewins, C.; Carbonnier, F.; Quinn, B. Wastewater Treatment Works (WwTW) as a Source of Microplastics in the Aquatic Environment. *Environ. Sci. Technol.* **2016**, *50*, 5800–5808. [\[CrossRef\]](#)
33. Yang, S.; Li, P.; Jiao, Y.; Li, Z.; Ruan, Y.; Yang, Q. A bibliometric analysis of microplastic pollution in aquatic environments from 2013 to 2023. *Sustain. Environ. Res.* **2025**, *35*, 19. [\[CrossRef\]](#)
34. Jiang, L.; Wang, M.; He, S.; Ren, J.; Zhang, T.; Cheng, Z. Bibliometrics and visualization analysis of microplastics research in water from 2011 to 2023. *J. Water Health* **2025**, *23*, 322–335. [\[CrossRef\]](#) [\[PubMed\]](#)
35. Yildirim, G.; Anindita, M.; Pan, X.; Rahman, S.; Alim, M.A.; Shaik, R.; Rahman, A. Bibliometric Insights into Microplastic Pollution in Freshwater Ecosystems. *Water* **2024**, *16*, 3237. [\[CrossRef\]](#)
36. Donthu, N.; Kumar, S.; Mukherjee, D.; Pandey, N.; Lim, W.M. How to conduct a bibliometric analysis: An overview and guidelines. *J. Bus. Res.* **2021**, *133*, 285–296. [\[CrossRef\]](#)
37. Zobkov, M.; Esiukova, E. Microplastics in Baltic bottom sediments: Quantification procedures and first results. *Mar. Pollut. Bull.* **2017**, *114*, 724–732. [\[CrossRef\]](#)
38. Halle, A.; Jeanneau, L.; Martignac, M.; Jardé, E.; Pedrono, B.; Brach, L.; Gigault, J. Nanoplastic in the North Atlantic Subtropical Gyre. *Environ. Sci. Technol.* **2017**, *51*, 13689–13697. [\[CrossRef\]](#)
39. Akhbarizadeh, R.; Moore, F.; Keshavarzi, B.; Moeinpour, A. Microplastics and potentially toxic elements in coastal sediments of Iran's main oil terminal (Khark Island). *Environ. Pollut.* **2017**, *220*, 720–731. [\[CrossRef\]](#)
40. Dobaradaran, S.; Schmidt, T.; Nabipour, I.; Khajeahmadi, N.; Tajbakhsh, S.; Saeedi, R.; Mohammadi, M.; Keshtkar, M.; Khorsand, M.; Ghasemi, F. Characterization of plastic debris and association of metals with microplastics in coastline sediment along the Persian Gulf. *Waste Manag.* **2018**, *78*, 649–658. [\[CrossRef\]](#)
41. Baini, M.; Fossi, M.; Galli, M.; Caliani, I.; Campani, T.; Finoia, M.; Panti, C. Abundance and characterization of microplastics in the coastal waters of Tuscany (Italy): The application of the MSFD monitoring protocol in the Mediterranean Sea. *Mar. Pollut.* **2018**, *133*, 543–552. [\[CrossRef\]](#)
42. Zhu, L.; Bai, H.; Chen, B.; Sun, X.; Qu, K.; Xia, B. Microplastic pollution in North Yellow Sea, China: Observations on occurrence, distribution and identification. *Sci. Total Environ.* **2018**, *636*, 20–29. [\[CrossRef\]](#)
43. Zhu, J.; Zhang, Q.; Li, Y.; Tan, S.; Kang, Z.; Yu, X.; Lan, W.; Cai, L.; Wang, J.; Shi, H. Microplastic pollution in the Maowei Sea, a typical mariculture bay of China. *Sci. Total Environ.* **2019**, *658*, 62–68. [\[CrossRef\]](#)
44. Mu, J.; Qu, L.; Jin, F.; Zhang, S.; Fang, C.; Ma, X.; Zhang, W.; Cheng, H.; Cong, Y.; Wang, J. Abundance and distribution of microplastics in the surface sediments from the northern Bering and Chukchi Seas. *Environ. Pollut.* **2019**, *245*, 122–130. [\[CrossRef\]](#) [\[PubMed\]](#)

45. Luo, W.; Su, L.; Craig, N.J.; Du, F.; Wu, C.; Shi, H. Comparison of microplastic pollution in different water bodies from urban creeks to coastal waters. *Environ. Pollut.* **2019**, *246*, 174–182. [[CrossRef](#)] [[PubMed](#)]
46. Wang, J.; Wang, M.; Ru, S.; Liu, X. High levels of microplastic pollution in the sediments and benthic organisms of the South Yellow Sea, China. *Sci. Total Environ.* **2019**, *651*, 1661–1669. [[CrossRef](#)] [[PubMed](#)]
47. Zhang, W.; Zhang, S.; Wang, J.; Wang, Y.; Mu, J.; Wang, P.; Lin, X.; Ma, D. Microplastic pollution in the surface waters of the Bohai Sea, China. *Environ. Pollut.* **2017**, *231*, 541–548. [[CrossRef](#)]
48. Zhao, J.; Ran, W.; Teng, J.; Liu, Y.; Liu, H.; Yin, X.; Cao, R.; Wang, Q. Microplastic pollution in sediments from the Bohai Sea and the Yellow Sea, China. *Sci. Total Environ.* **2018**, *640–641*, 637–645. [[CrossRef](#)]
49. Aslam, H.; Ali, T.; Mortula, M.M.; Attaelmanan, A.G. Evaluation of microplastics in beach sediments along the coast of Dubai, UAE. *Mar. Pollut. Bull.* **2020**, *150*, 110739. [[CrossRef](#)]
50. Ali, T.; Mortula, M.; Mohsen, B.; Dronjak, L.; Gawai, R.; Atabay, S.; Khan, Z.; Fattah, K. Evaluating Microplastic Pollution Along the Dubai Coast: An Empirical Model Combining On-Site Sampling and Sentinel-2 Remote Sensing Data. *J. Sustain. Dev. Energy Water Environ. Syst.* **2024**, *12*, 1110482. [[CrossRef](#)]
51. Browne, M.A.; Galloway, T.S.; Thompson, R.C. Spatial Patterns of Plastic Debris along Estuarine Shorelines. *Environ. Sci. Technol.* **2010**, *44*, 3404–3409. [[CrossRef](#)]
52. Pivokonsky, M.; Cermakova, L.; Novotna, K.; Peer, P.; Cajthaml, T.; Janda, V. Occurrence of microplastics in raw and treated drinking water. *Sci. Total Environ.* **2018**, *643*, 1644–1651. [[CrossRef](#)]
53. Baldwin, A.; Corsi, S.; Mason, S. Plastic Debris in 29 Great Lakes Tributaries: Relations to Watershed Attributes and Hydrology. *Environ. Sci. Technol.* **2016**, *50*, 10377–10385. [[CrossRef](#)] [[PubMed](#)]
54. Nel, H.; Dalu, T.; Wasserman, R. Sinks and sources: Assessing microplastic abundance in river sediment and deposit feeders in an Austral temperate urban river system. *Sci. Total Environ.* **2018**, *612*, 950–956. [[CrossRef](#)] [[PubMed](#)]
55. Połec, M.; Aleksander-Kwaterczak, U.; Wator, K.; Kmiecik, E. The occurrence of microplastics in freshwater systems—Preliminary results from Krakow (Poland). *Geol. Geophys. Environ.* **2018**, *44*, 391–412. [[CrossRef](#)]
56. Di, M.; Wang, J. Microplastics in surface waters and sediments of the Three Gorges Reservoir, China. *Sci. Total Environ.* **2018**, *616–617*, 1620–1627. [[CrossRef](#)]
57. Wang, W.; Yuan, W.; Chen, Y.; Wang, J. Microplastics in surface waters of Dongting Lake and Hong Lake, China. *Sci. Total Environ.* **2018**, *633*, 539–545. [[CrossRef](#)]
58. Xiong, X.; Zhang, K.; Chen, X.; Shi, H.; Luo, Z.; Wu, C. Sources and distribution of microplastics in China's largest inland lake-Qinghai Lake. *Environ. Pollut.* **2018**, *235*, 899–906. [[CrossRef](#)]
59. Zhang, K.; Su, J.; Xiong, X.; Wu, X.; Wu, C.; Liu, J. Microplastic pollution of lakeshore sediments from remote lakes in Tibet plateau, China. *Environ. Pollut.* **2016**, *219*, 450–455. [[CrossRef](#)]
60. Su, L.; Xue, Y.; Li, L.; Yang, D.; Kolandhasamy, P.; Li, D.; Shi, H. Microplastics in Taihu Lake, China. *Environ. Pollut.* **2016**, *216*, 711–719. [[CrossRef](#)]
61. Fischer, E.; Paglialonga, L.; Czech, E.; Tamminga, M. Microplastic pollution in lakes and lake shoreline sediments—A case study on Lake Bolsena and Lake Chiuse (central Italy). *Environ. Pollut.* **2016**, *213*, 648–657. [[CrossRef](#)]
62. Sruthy, S.; Ramasamy, E. Microplastic pollution in Vembanad Lake, Kerala, India: The first report of microplastics in lake and estuarine sediments in India. *Environ. Pollut.* **2017**, *222*, 315–322. [[CrossRef](#)]
63. Vaughan, R.; Turner, S.D.; Rose, N.L. Microplastics in the sediments of a UK urban lake. *Environ. Pollut.* **2017**, *229*, 10–18. [[CrossRef](#)]
64. Sighicelli, M.; Pietrelli, L.; Lecce, F.; Iannilli, V.; Falconieri, M.; Coscia, L.; Di Vito, S.; Nuglio, S.; Zampetti, G. Microplastic pollution in the surface waters of Italian Subalpine Lakes. *Environ. Pollut.* **2018**, *236*, 645–651. [[CrossRef](#)] [[PubMed](#)]
65. Hendrickson, E.; Minor, E.; Schreiner, K. Microplastic Abundance and Composition in Western Lake Superior as Determined via Microscopy, Pyr-GC/MS, and FTIR. *Environ. Sci. Technol.* **2018**, *52*, 1787–1796. [[CrossRef](#)] [[PubMed](#)]
66. Yuan, W.; Liu, X.; Wang, W.; Di, M.; Wang, J. Microplastic abundance, distribution and composition in water, sediments, and wild fish from Poyang Lake, China. *Ecotoxicol. Environ. Saf.* **2019**, *170*, 180–187. [[CrossRef](#)] [[PubMed](#)]
67. Panno, S.V.; Kelly, W.R.; Scott, J.; Zheng, W.; McNeish, R.E.; Holm, N.; Hoellein, T.J.; Baranski, E.L. Microplastic Contamination in Karst Groundwater Systems. *Ground Water* **2019**, *57*, 189–196. [[CrossRef](#)]
68. Johnson, A.C.; Ball, H.; Cross, R.; Horton, A.A.; Jürgens, M.D.; Read, D.S.; Vollertsen, J.; Svendsen, C. Identification and Quantification of Microplastics in Potable Water and Their Sources within Water Treatment Works in England and Wales. *Environ. Sci. Technol.* **2020**, *54*, 12326–12334. [[CrossRef](#)]
69. Selvam, S.; Jesuraja, K.; Venkatramanan, S.; Roy, P.D.; Kumari, V.J. Hazardous microplastic characteristics and its role as a vector of heavy metal in groundwater and surface water of coastal south India. *J. Hazard. Mater.* **2021**, *402*, 123786. [[CrossRef](#)]
70. Mintenig, S.M.; Löder, M.G.J.; Pimpke, S.; Gerdt, G. Low numbers of microplastics detected in drinking water from ground water sources. *Sci. Total Environ.* **2019**, *648*, 631–635. [[CrossRef](#)]

71. Samandra, S.; Johnston, J.M.; Jaeger, J.E.; Symons, B.; Xie, S.; Currell, M.; Ellis, A.V.; Clarke, B.O. Microplastic contamination of an unconfined groundwater aquifer in Victoria, Australia. *Sci. Total Environ.* **2022**, *802*, 149727. [\[CrossRef\]](#)
72. Ganesan, M.; Nallathambi, G.; Srinivasalu, S. Fate and Transport of Microplastics from Water Sources. *Curr. Sci.* **2019**, *117*, 1879–1885. [\[CrossRef\]](#)
73. Tatan, B.; Mortula, M.M.; Ali, T. Evaluation of microplastics in groundwater within surrounding areas of Sajaa landfill site, Sharjah, United Arab Emirates. *Bioresour. Technol. Rep.* **2025**, *30*, 102114. [\[CrossRef\]](#)
74. Wang, Z.; Lin, T.; Chen, W. Occurrence and removal of microplastics in an advanced drinking water treatment plant (ADWTP). *Sci. Total Environ.* **2020**, *700*, 134520. [\[CrossRef\]](#) [\[PubMed\]](#)
75. Kosuth, M.; Mason, S.A.; Wattenberg, E.V. Anthropogenic contamination of tap water, beer, and sea salt. *PLoS ONE* **2018**, *13*, e0194970. [\[CrossRef\]](#) [\[PubMed\]](#)
76. Kirstein, I.V.; Hensel, F.; Gomiero, A.; Iordachescu, L.; Vianello, A.; Wittgren, H.B.; Vollertsen, J. Drinking plastics?—Quantification and qualification of microplastics in drinking water distribution systems by μ FTIR and Py-GCMS. *Water Res.* **2021**, *188*, 116519. [\[CrossRef\]](#) [\[PubMed\]](#)
77. Shruti, V.C.; Pérez-Guevara, F.; Kutralam-Muniasamy, G. Metro station free drinking water fountain—A potential “microplastics hotspot” for human consumption. *Environ. Pollut.* **2020**, *261*, 114227. [\[CrossRef\]](#)
78. Weber, F.; Kerpen, J.; Wolff, S.; Langer, R.; Eschweiler, V. Investigation of microplastics contamination in drinking water of a German city. *Sci. Total Environ.* **2021**, *755*, 143421. [\[CrossRef\]](#)
79. Tong, H.; Jiang, Q.; Hu, X.; Zhong, X. Occurrence and identification of microplastics in tap water from China. *Chemosphere* **2020**, *252*, 126493. [\[CrossRef\]](#)
80. Almaiman, L.; Aljomah, A.; Bineid, M.; Aljeldah, F.M.; Aldawsari, F.; Liebmann, B.; Lomako, I.; Sexlinger, K.; Alarfaj, R. The occurrence and dietary intake related to the presence of microplastics in drinking water in Saudi Arabia. *Environ. Monit. Assess.* **2021**, *193*, 390. [\[CrossRef\]](#)
81. Feld, L.; Silva, V.H.D.; Murphy, F.; Hartmann, N.B.; Strand, J. A Study of Microplastic Particles in Danish Tap Water. *Water* **2021**, *13*, 2097. [\[CrossRef\]](#)
82. Tse, Y.-T.; Chan, S.M.; Sze, E.T. Quantitative Assessment of Full Size Microplastics in Bottled and Tap Water Samples in Hong Kong. *Int. J. Environ. Res. Public Health* **2022**, *19*, 13432. [\[CrossRef\]](#)
83. Temam, R.; Mortula, M.M. Leaching of microplastics from PVC pipes under stagnant conditions. *Desalin. Water Treat.* **2023**, *311*, 243–252. [\[CrossRef\]](#)
84. Hammodat, A.R.; Nassar, S.; Mortula, M.M.; Shamsuzzaman, M. Factors affecting the leaching of micro and nanoplastics in the water distribution system. *J. Environ. Manag.* **2023**, *345*, 118779. [\[CrossRef\]](#) [\[PubMed\]](#)
85. Mason, S.A.; Garneau, D.; Sutton, R.; Chu, Y.; Ehmann, K.; Barnes, J.; Fink, P.; Papazissimos, D.; Rogers, D.L. Microplastic pollution is widely detected in US municipal wastewater treatment plant effluent. *Environ. Pollut.* **2016**, *218*, 1045–1054. [\[CrossRef\]](#)
86. Mintenig, S.M. Identification of microplastic in effluents of waste water treatment plants using focal plane array-based micro-Fourier-transform infrared imaging. *Water Res.* **2017**, *108*, 365–372. [\[CrossRef\]](#) [\[PubMed\]](#)
87. Talvitie, J.; Mikola, A.; Koistinen, A.; Setälä, O. Solutions to microplastic pollution Removal of microplastics from wastewater effluent with advanced wastewater treatment technologies. *Water Res.* **2017**, *123*, 401–407. [\[CrossRef\]](#)
88. Leslie, H.A.; Brandsma, S.H.; van Velzen, M.J.M.; Vethaak, A.D. Microplastics en route: Field measurements in the Dutch river delta and Amsterdam canals, wastewater treatment plants, North Sea sediments and biota. *Environ. Int.* **2017**, *101*, 133–142. [\[CrossRef\]](#)
89. Talvitie, J.; Mikola, A.; Setälä, O.; Heinonen, M.; Koistinen, A. How well is microlitter purified from wastewater: A detailed study on the stepwise removal of microlitter in a tertiary level wastewater treatment plant. *Water Res.* **2017**, *109*, 164–172. [\[CrossRef\]](#)
90. Magni, S.; Binelli, A.; Pittura, L.; Avio, C.G.; Della Torre, C.; Parenti, C.C.; Gorbi, S.; Regoli, F. The fate of microplastics in an Italian Wastewater Treatment Plant. *Sci. Total Environ.* **2019**, *652*, 602–610. [\[CrossRef\]](#)
91. Edo, C.; González-Pleiter, M.; Leganés, F.; Fernández-Piñas, F.; Rosal, R. Fate of microplastics in wastewater treatment plants and their environmental dispersion with effluent and sludge. *Environ. Pollut.* **2020**, *259*, 113837. [\[CrossRef\]](#)
92. El Hayany, B.; El Fels, L.; Quénéa, K.; Dignac, M.-F.; Rumpel, C.; Gupta, V.K.; Hafidi, M. Microplastics from lagooning sludge to composts as revealed by fluorescent staining- image analysis, Raman spectroscopy and pyrolysis-GC/MS. *J. Environ. Manag.* **2020**, *275*, 111249. [\[CrossRef\]](#)
93. Xu, Q.; Gao, Y.; Xu, L.; Shi, W.; Wang, F.; LeBlanc, G.A.; Cui, S.; An, L.; Lei, K. Investigation of the microplastics profile in sludge from China’s largest Water reclamation plant using a feasible isolation device. *J. Hazard. Mater.* **2020**, *388*, 122067. [\[CrossRef\]](#)
94. Horton, A.A.; Cross, R.K.; Read, D.S.; Jürgens, M.D.; Ball, H.L.; Svendsen, C.; Vollertsen, J.; Johnson, A.C. Semi-automated analysis of microplastics in complex wastewater samples. *Environ. Pollut.* **2021**, *268*, 115841. [\[CrossRef\]](#) [\[PubMed\]](#)
95. Petroody, S.S.A.; Hashemi, S.H.; van Gestel, C.A.M. Transport and accumulation of microplastics through wastewater treatment sludge processes. *Chemosphere* **2021**, *278*, 130471. [\[CrossRef\]](#) [\[PubMed\]](#)

96. Oßmann, B.E.; Sarau, G.; Holtmannspötter, H.; Pischetsrieder, M.; Christiansen, S.H.; Dicke, W. Small-sized microplastics and pigmented particles in bottled mineral water. *Water Res.* **2018**, *141*, 307–316. [[CrossRef](#)] [[PubMed](#)]
97. Zuccarello, P.; Ferrante, M.; Cristaldi, A.; Copat, C.; Grasso, A.; Sangregorio, D.; Fiore, M.; Conti, G.O. Exposure to microplastics associated to plastic bottles mineral water consumption: The first quantitative study. *Water Res.* **2019**, *157*, 365–371. [[CrossRef](#)]
98. Zhou, X.J.; Wang, J.; Li, H.Y.; Zhang, H.M.; Zhang, D.L. Microplastic pollution of bottled water in China. *J. Water Process Eng.* **2021**, *40*, 101884. [[CrossRef](#)]
99. Samandra, S.; Mescall, O.J.; Plaisted, K.; Symons, B.; Xie, S.; Ellis, A.V.; Clarke, B.O. Assessing exposure of the Australian population to microplastics through bottled water consumption. *Sci. Total Environ.* **2022**, *837*, 155329. [[CrossRef](#)]
100. Praveena, S.M.; Ariffin, N.I.S.; Nafisyah, A.L. Microplastics in Malaysian bottled water brands: Occurrence and potential human exposure. *Environ. Pollut.* **2022**, *315*, 120494. [[CrossRef](#)]
101. Li, X.; Yu, Y.; Yang, M.; Wen, S.; Zhang, J. Tracking Microplastics Contamination in Drinking Water Supply Chain in Haikou, China: From Source to Household Taps. *Toxics* **2024**, *12*, 793. [[CrossRef](#)]
102. Makhdoumi, P.; Amin, A.A.; Karimi, H.; Pirsaeheb, M.; Kim, H.; Hossini, H. Occurrence of microplastic particles in the most popular Iranian bottled mineral water brands and an assessment of human exposure. *J. Water Process Eng.* **2021**, *39*, 101708. [[CrossRef](#)]
103. Parveen, N.; Ranjan, V.P.; Chowdhury, S.; Goel, S. Occurrence and Potential Health Risks Due to Trihalomethanes and Microplastics in Bottled Water. *Environ. Eng. Sci.* **2022**, *39*, 523–534. [[CrossRef](#)]
104. Li, H.; Zhu, L.; Ma, M.; Wu, H.; An, L.; Yang, Z. Occurrence of microplastics in commercially sold bottled water. *Sci. Total Environ.* **2023**, *867*, 161553. [[CrossRef](#)]

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