A systematic review of microplastic pollution in rivers across Asia

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Abstract

Microplastics are widely distributed in the aquatic ecosystem globally. They pose potential risks and harm to the ecosystem and human health. Contamination of river environments by microplastics has raised concern due to its negative effect on the aquatic system. Asian rivers serve the world's most populous continent, encompassing many developing countries experiencing rapid development and associated environmental challenges. In this article, we critically reviewed research papers published between 2011 and 2024 that reported microplastic contamination in major river systems across Asia. These papers examined the occurrence, distribution, sampling methods, sample preparation and identification techniques, and characterization of microplastics. Our review found that the majority of microplastic studies in Asian rivers have been conducted in China. Other countries reporting riverine microplastic pollution include India, Malaysia, Taiwan, Japan, South Korea, Thailand, Nepal, Iran, Pakistan, Hongkong, Vietnam, Cambodia, Bangladesh, Maldives, and Indonesia. The reported microplastic concentration varied widely, ranging from just a few particles to as high as 4,200,000 particles per cubic meter. Fibers were identified as the most dominant type of microplastics among fragments, foam, pellets, and film. A wide range of colors was observed, including red, black, blue, white, yellow, green, transparent, with white being the most prevalent one. Among the identified polymers, polypropylene was the most common in the river surface waters. Other reported materials included poly(ethylene-propylene), polyamide, polystyrene, polyurethane, cellulose, polyethylene terephthalate, silicone, polyester, rubber, and plastic coatings. Identified sources of microplastics identified domestic sewage, fishing, shipping activities, beautifying products and personal care products. Finally, this review highlights the urgent need for further research on microplastic pollution in Asian river system.

Keywords: Aquatic ecosystem, Emerging contaminant, Water pollution, Microplastics characterization.

1. Introduction

Plastic materials primarily produced from fossil fuels such as petroleum, natural gas, or coal are meant to meet the needs of end-manufactured goods. They play a vital role in many areas of modern human life such as in packaging, building, construction, electronic devices, agriculture, medical facilities, and transport sectors[1]. There has been a continued growth of plastic manufacturing in the past several decades reaching 335 million tons in 2016 [1] which has resulted in the presence of microplastics (MP) in air, animal tissues, soil, and water bodies.

Plastic particles with a size less than 5 mm in diameter (or length) are termed as MP and they are found, primarily, in the form of fibers, foams, and filaments [2]. The primary sources of MP are plastic raw materials and personal care products. Secondary sources are fragmentation products of original or large plastic particles [3] such as paint flakes, debris from tires, and particles from industrial manufacturing [4].

Environmental contamination by microplastics is an emerging concern. MP have the potential to cause risk and harm to the ecosystem and human health [5,6]. Ingestion and consumption of microplastics by organisms may cause mechanical inflammatory responses [7]. The ingestion may introduce routes for hazardous substances including endogenous plastic additives, and pathogenic microorganisms, and take up pollutants from the ambient environment into the aquatic food web. The human body is exposed to the microplastics through the ingestion of food containing microplastics, inhalation of microplastics in air, and dermal contact of these particles [8].

Microplastics are widely distributed in the aquatic, terrestrial, marine environment, and air, therefore have become a contaminant of global concern [9,10]. It is projected that at least 8 million tons of plastic waste ends in the global oceans each year and by 2050 there will be more plastics in our ocean than the fish [11].

Rivers are major pathways in carrying primary microplastics released from the plastic industry and anthropogenic activities into the ocean [12,13]. By the fragmentation of plastic materials, rivers can be the secondary source of microplastics, which are disintegrated by photooxidative degradation and broken by human activity [14]. Contamination of river environments by microplastics has raised concern due to its negative effect on the aquatic system. Asian rivers serve the largest and most populated continent of Asia that host many developing countries with rapid development and environmental challenges. Although publications covering microplastics in river waters has been increasing, they are limited to a few river systems in Asia [15–17].

In this article, we systematically reviewed research papers reporting microplastic contamination in Asian rivers. Our analysis covers the occurrence, distribution, morphology, material properties, and potential sources of microplastics in the rivers. The majority of studies to date have been conducted in China, with additional reports from countries such as India, Malaysia, Taiwan, Japan, South Korea, Thailand, Nepal, and Indonesia. The concentration of microplastics widely varied, reaching as high as 4,200,000 particles/m^3[18] which is a matter of concern. This review also emphasizes the need for further studies on microplastic contamination in the region. The paper is organized into nine major sections, including introduction (the current section), methodology, occurrence of microplastics in Asian Rivers, sample collection and preparation and detection of microplastics, abundance of microplastics, morphological characteristics of microplastics, material characteristics, sources of microplastics in river water, and conclusions and future perspectives.

2. Methodology

We searched a combination of keywords utilizing advanced search on Google Scholar with *Microplastics and River* as a key words and with at least one of the following words: Asia, Afghanistan, Armenia, Azerbaijan, Bahrain, Bangladesh, Bhutan, Brunei, Cambodia, China, Cyprus, Georgia, India, Indonesia, Iran, Iraq, Israel, Japan, Jordan, Kazakhstan, Kuwait, Kyrgyzstan, Laos, Lebanon, Malaysia, Maldives, Mongolia, Myanmar (Burma), Nepal, North Korea, Oman, Pakistan, Palestine, Philippines, Qatar, Russia, Saudi Arabia, Singapore, South Korea, Sri Lanka, Syria, Taiwan, Tajikistan, Thailand, Timor-Leste, Turkey, Turkmenistan, United Arab Emirates, Uzbekistan, Vietnam, and Yemen. The keywords were searched in the title of the publications between 2011 and 2024. The search resulted in 229 documents in this period. After further careful reading of abstract these documents, we narrowed down to 85 documents to include in this review and excluded 144 documents that did not report primary data of microplastics in Asian river water. The exclusion and inclusion criteria are described in Figure 1.

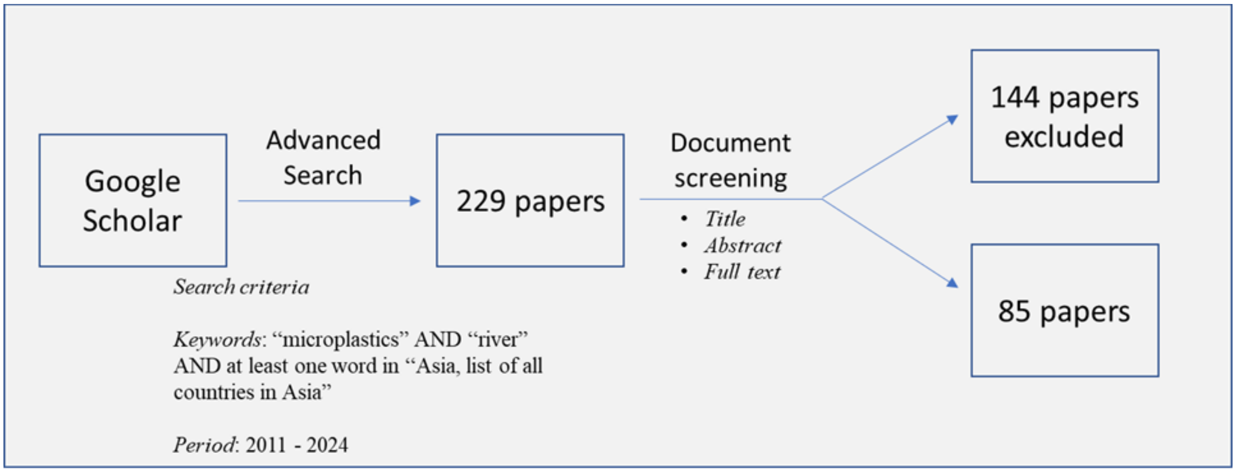

Figure 1: A flowchart showing the process of literature search used in this review.

3. Occurrence of microplastics in Asian Rivers

Asia is the most populous continent, home to approximately 60% of the global population. Many Asian countries are developing nations undergoing rapid economic growth while simultaneously grappling with contemporary environmental challenges [19]. Rivers in this region play a critical role in supporting agriculture, aquaculture, and range of domestic and aquatic uses.

We identified only 85 research papers reporting microplastic contamination in Asian river waters published between 2011 and 2024. Notably, all these papers were published within the last seven years (2018 – 2024), with no publications prior to 2018 (*see* Figure 2). A few papers have been reported in 2018 and 2019, followed by a marked increase in publications after 2020.

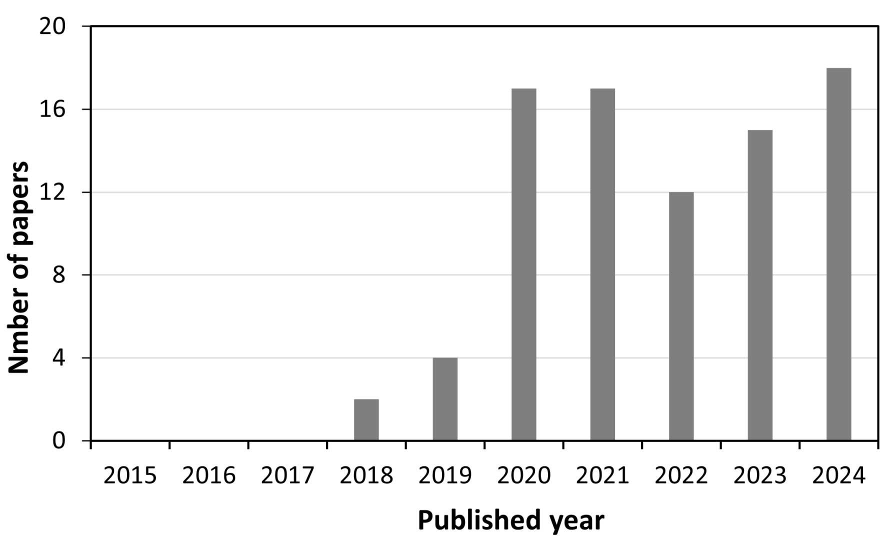

Figure 2: Trend of number of papers published in microplastics in Asian rivers.

Out of 52 countries in Asia, at least one study on microplastics in freshwater system has been reported from following 21 countries - Afghanistan, Bangladesh, Cambodia, China, Georgia, India, Indonesia, Iran, Japan Malaysia, Mongolia, Nepal, Pakistan, Philippines, Russia, South Korea, Sri Lanka, Taiwan, Thailand, Turkey, and Vietnam. The majority of studies focused on Chinese rivers. In contrast, no studies were found from following countries: Armenia, Azerbaijan, Bahrain, Bhutan, Brunei, Cyprus, Iraq, Israel, Jordan, Kazakhstan, Kuwait, Kyrgyzstan, Laos, Lebanon, Maldives, Myanmar (Burma), North Korea, Oman, Palestine, Qatar, Saudi Arabia, Singapore, Syria, Tajikistan, Timor-Leste (East Timor), Turkmenistan, United Arab Emirates, Uzbekistan, and Yemen.

The spatial distribution of sampling sites across Asian rivers, as described in the reviewed papers, from where surface water samples were collected for microplastics analysis is shown in Figure 3. The river basins and major rivers in the map are based on data from the FAO[20] and World Bank[21]. The Iranian river basins were sourced from OpenStreetMap[22]. Blue dots on the map indicate water sampling locations, while blue lines represent river courses, as reported in the reviewed papers included in this review. The coordinates of the sampling locations were extracted from the respective papers, and the map was generated using arcGIS.

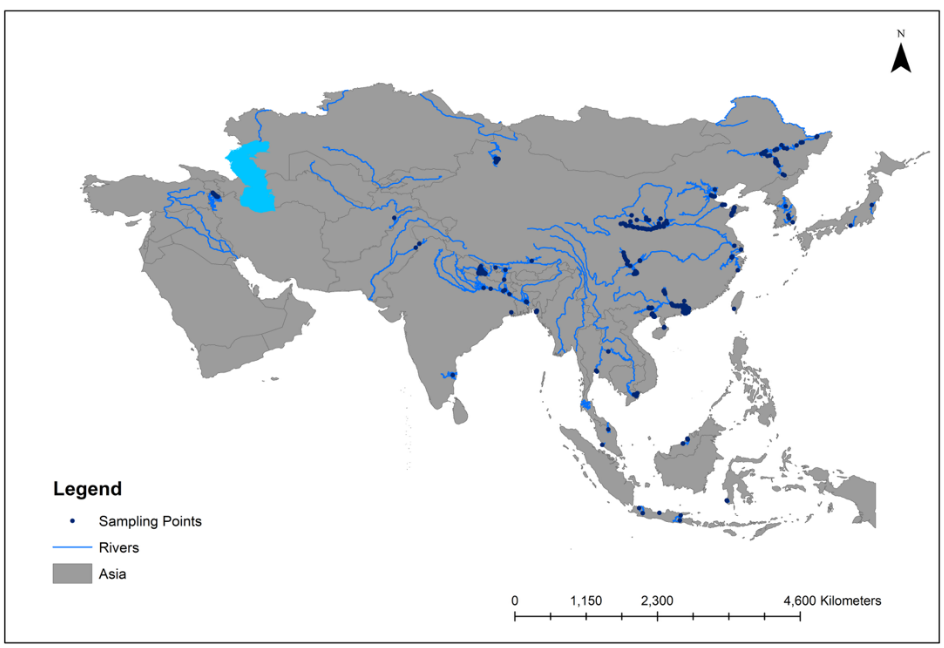

Figure 3: River systems in Asia showing sample collection sites for microplastics detection reported in the 85 papers included in this review.

The rivers shown on the map represent major freshwater sources in Asia. However, they also serve as recipients of domestic and industrial waste, much of which is discharged without prior treatment. A summary of reviewed papers, including river names, microplastic concentrations, size ranges, material types, and morphological characteristics is provided in Table 1.

Table 1: Overview of key parameters characterizing microplastics in river waters across Asia.

The majority of microplastic data in river water samples have been reported from rivers in China (*see* Table 1), including the Tuojiang, Wei, Lijiang, Qing, Yulin, Haihe, Manas, Chishui, Pearl (Xijiang), Beijiang, Yellow, West, Yangtze, Pum Qu, Songhua, Lhasa, Dagu, Meishe, Southern Jiangsu Canal, Yulong, Songhua, Qiantang, Yongjiang, and Dafeng rivers. Outside China, microplastic pollution has been reported in several other Asian rivers - the Ganga and Cooum Rivers in India; Klang, Niah, Kemena, Langat, and Kelantan Rivers in Malaysia; Fengshan River from Taiwan; Arakawa and Umeda rivers from Japan; Nakdong River and Han River from South Korea; Chao Phraya River, Tapi-Phumduang River, Chi river, and Pong river from Thailand; Tamor, Sapta Koshi, Sun Koshi and Arun rivers from Nepal; Citarum River, Surabaya River, Cisadane river, Tallo river, Pekalongan river and, Metro riverfrom Indonesia; Maozhou River from Hongkong; Karnafully River, and Buriganga River, Karnaphuli River from Bangladesh; Zayandeh-rud River, and Haraz River, Aras River from Iran; Ravi River and Swat River Pakistan; and Mekong River (Tien river) in Vietnam.

4. Sample collection, preparation, and detection of microplastics

Although the study on microplastics has a long history of more than two hundred years, the methodologies for sample collection, processing, digestion, pretreatment, quantification, detection, and identification have not been standardized yet [23]. The distribution of MP in water is impacted by their physical, morphological, and chemical characteristics and environmental situations like water density, current, wind, rain, and waves. Therefore, sampling spot and depth along with sample collection methodology determines the abundance of microplastics recovered [23]. The sample collection methodology should also consider the fact that microplastics tend to float on the surface of the water due to its less density than water [24].

Different sample collection techniques such as grab, bulk, purposive, and volume reduced sampling methodologies were used in the papers we reviewed. Samples were collected using steel buckets, glass bottles, manta trawl and plankton nets. Nets of various sizes are used to collect water samples in open bodies. The National Oceanic and Atmospheric Administration of the USA suggests a net of 333 um mesh size net for the collection of samples which can cover a large area of samples and reduce water volume [24]. A large volume of water should be collected to make the samples representative. Mantra net is suitable for the collection of samples that float on the surface of water bodies [25].

As water samples from rivers may contain organic matter, a treatment process may be needed to remove the organic, inorganic, and environmental debris before quantifying microplastics [23,26]. The water samples were proceeded with digestion methods to remove organic matter. The sample preparation method should not affect the morphological, physical, and chemical components of polymers [27,28]. Most of the papers included in this review reported the use of H_2O_2 solution and Fenton's reagent (H_2O_2 with ferrous ion catalyst) for digestion. The sample preparation also involves density separation method to improve the identification and detection of microplastics. Most of the papers reported the use of NaCl and a few used $ZnCl_2$ or NaI, lithium metatungstate [18] for density separation. These salts are chosen based on their availability, cost, and efficiency for separating microplastics at different densities [26]. Microplastics in the samples were then segregated using different sizes of mesh. The pore size of the filer or sieve's mesh differs considerably and the size of detected microplastics depends upon the pore or mesh size [23].

Physical characterization of the MP was carried out by microscopic methods, such as stereo microscope and dissecting microscope integrated with digital camera to capture images. Furthermore, to distinguish the microplastics from other particles, a melting test, and hot needle were also used [29,30]. Chemical characterization was mostly performed using Fourier transform infrared (FT-IR) in attenuated total reflection mode and micro-Raman spectroscopy. Few papers used scanning electron microscopy for morphological characterization [31]. We refer to our recent review on analytical methods for microplastics analysis for details [26].

5. Abundance of microplastics

The concentration of microplastics was found to be widely variable. The range of particles is from a few items to as high as 4,200,000 items/m^3. The highest concentration of microplastics has been reported in Ganga river in India[32]. Similarly, a section of Yellow river in China had very high concentration of microplastics, as high as 2510830 during September 2021[33]. Additionally, Wei river, Manas river, Chishui river, Pearl (Xijiang) river), Yangtze river, Songhua river Meishe river, and Maozhou river contained microplastic particles more than 10000 per m^3 of water (Table 1). Pekalongan and Metro rivers in Indonesia, Kelantan, Langat, and Kemena rivers in Malaysia, Saptagandaki in Nepal, Buriganga in Bangladesh and Ravi rivers in Pakistan are also highly contaminated with microplastics (>10000 per m^3). But few rivers such as Haihe River in northern China had relatively fewer microplastics (range: 0.69 to 74.95 items/m^3) [34]. Similarly microplastic concentration in the surface water in Han River, South Korea was 0-42.9 particles/m^3 [35]. The Koshi river basin in Nepal had MPs ranging from 142 in Arun river to 308 in Sunkoshi river [36]. In most of the studies, we have compared the abundance in particles per cubic meter. In some cases, the results are reported in particles or items per square kilometer. Most of the papers reported their results in terms of mean±standard deviation but few did not report the error associated with the measurement. The abundance of plastics particles depends on several factors including contamination of the river itself, sampling methods and sampling season, laboratory methods and most importantly the cut-off size of the particles employed during the whole process. Studies have shown that smaller particles are found more in the samples. Therefore, the comparison may not be realistic but gives the extent of river contamination.

6. Morphological characteristics, size, and color of microplastics in river water

The effect and fate of microplastics depend on their feathers and characteristics [37]. They exist in different shapes, sizes, densities, colors, and polymer types[36–38]. The shapes of microplastics depend on geological process like erosion and degradation, and the original form of primary microplastics [37,39]. It has been suggested that degraded microplastics with sharp edges show a current introduction into the environment while smooth boundaries are associated with a large residence time [38].

Various shapes of microplastics like fiber, fragment, foam, pellet, film, spherule, granule, line, string, sheet, block, flake, bead, debris, filament, and cube particles were detected in the reviewed studies of river water. The fibers are the most common microplastics which are followed by fragments detected in river water. (*see* Table 1). Representative photographs of different forms and sizes of microplastics and their FT-IR spectra are given in figure 4.

Generally, microplastics included a wide range of sizes, ranging from 1µm to 5mm in length [40]. In Haihe River [34], the dominant particle size in the water column was 200–500 µm, accounting for 34.1 ± 7.2% of the total MPs, followed by 100–200 µm (23.3 ± 3.7%) and 500–1000 µm (16.9 ± 4.1%) size ranges and size of < 1mm contributed high proportions of microplastics. Smaller MPs dominated most of the rivers. Larger MPs (e.g., ~5mm) dominated only in a few rivers such as Lijiang, Qing, Ganga and Citarum (*see* Table 1).

Microplastics can be of different colors [41]. Colored (pigmented, translucent), non-colored (white, transparent, non-pigmented), and opaque (black, dark) all kinds of MPs were detected in the reviewed studies. In the Wei River, 93.6% includes colorless microplastics, red (2.8%), black (2.2%), and blue (1.6%). Similarly, in the Chao Phraya River Estuary, Thailand white and transparent particles were detected in the majority of surface water samples with 50.6%, and 16.4%, respectively, and blue (14.5%) and green (7.7%) [42]. In addition, multiple colors of microplastic were observed in Pearl River including red, black, blue, white, yellow, green, and transparent and white (65.6%) is the most dominant microplastic detected [43]. In some studies, there were no descriptions or identification of colored microplastics. The colored microplastics including red, blue, green, and black are ingested by goldfishes and mackerels [44].

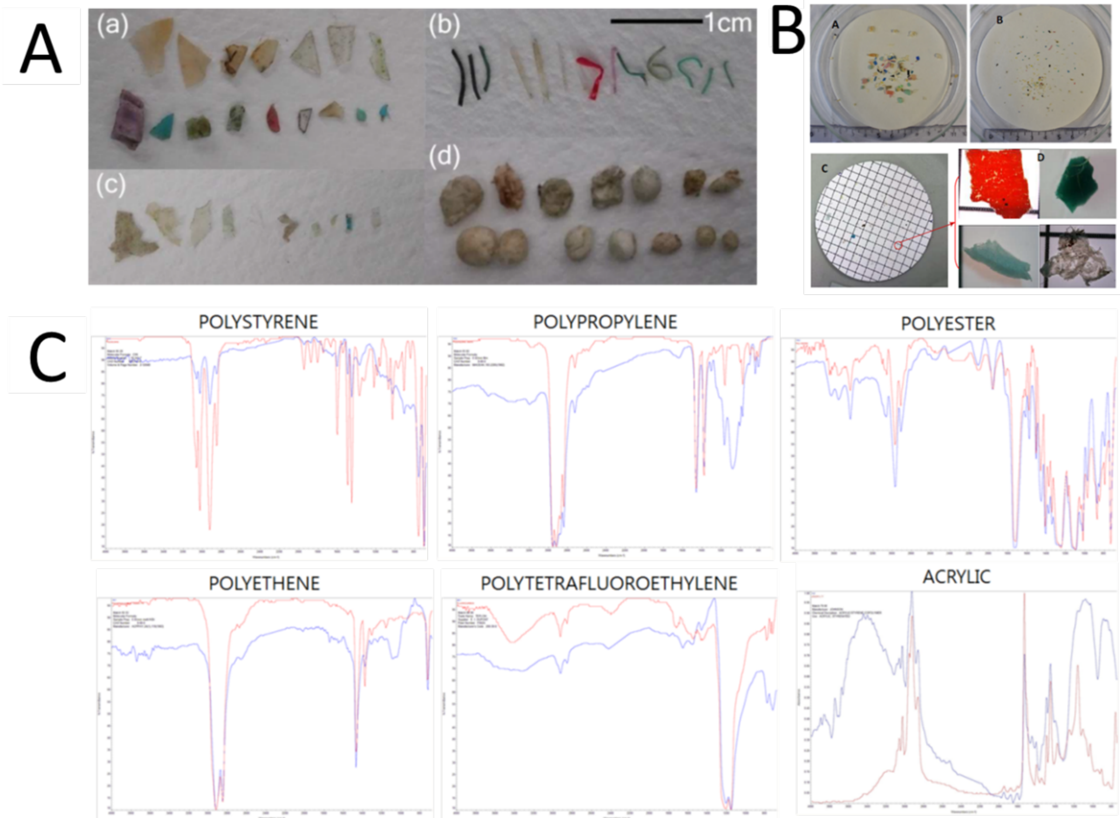

Figure 4: (A) Morphological characteristics of microplastics. (a) fragment, (b) fiber, (c) film and (d) foam [45](B) Microplastics of different size ranges (A) 1-5 mm, (B) 0.5-1 mm, (C) 0.053-0.5 mm, (D) MPs under a microscope at 10x magnification. [46](C) FT-IR spectrums of sample (red line) and reference (blue line) [35].

7. Material characteristics of microplastics

Commonly used plastic materials consist of different polymer types, including polypropylene (PP), polyethylene (PE), polystyrene (PS), polyvinylchloride (PVC), polyethylene terephthalate (PET), polyamides (PA), etc. [47]. These are the common types of plastic polymers released into the environment[38,48].

Dominant polymer types of microplastics detected in Asian rivers were PE, PP, PET, and PS. In West River in China, PP was abundant in comparison to other samples which covers 40% and that was followed by PE (29%) and PS (20%)[49]. Synthetic polymers in Haihe River include PE (28.2%), poly (ethylene-propylene) (25.9%), PA (13.2%), PS (10.3%), polyurethane (4.6%), cellulose (1.7%), and PET (1.2%)[34]. Additionally, in the Han River, polymers include 23.1% of silicone, 16.9% PS, 15.4% PP, 13.8% polyester, and 30.8% of other plastic particles[35]. In Surabaya River, a total of five different types of microplastics including low-density polyethylene terephthalate (LDPE), PP, PS, PE, and PET were identified by FTIR. LDPE was the most dominant microplastics in surface (44–68%), middle depth (39–73%), and river bottom (39–73%), followed by PP and PE in all three depths[50].

8. Sources of microplastics in river water

Identification of potential sources of microplastics is still challenging. Aquaculture activities and industrial products were identified as the causes of microplastics pollution in the Qin River[51]. In Haihe River, rubber, plastics coating, fragments, raw materials in industrial resins and leak out during transportation and production, plastic bags, packaging materials, textiles, fishing activities such as fishing nets, rope, and materials used in food packaging, laboratory ware were reported as the main sources of microplastics[34]. Effluent from the wastewater treatment plant contributed high levels of microplastics in surface water and surface runoff, fishing, shipping activities, beautifying products, and personal care products were the main sources of microplastics in Yulin River[52]. In the Tuojiang River basin, poor water quality was an indicator of more microplastics pollution indicating the impact of secondary industries of cities with higher gross domestic product [31]. The MPs in Koshi river basin in Nepal were coming from untreated sewage from effluents and solid wastes from households, cities, agricultural sectors, urbanization, and atmospheric shipping [36].

Fibers in the water most likely released from clothing, carpet, textiles, and washing [53]. Films are primarily released into the environment from plastic bags and packaging materials. Foam-shaped microplastic comes into the environment from styrofoam[54]. Pellets are spilled during transportation and processing [55], microbeads used in cosmetic products, and air-blasting cleaner in the industry [56]. Colored and transparent microplastics are released from the packaging, clothing, and other plastic items [57].

9. Conclusions and future perspectives

Microplastics have emerged as a significant global contaminant in river systems. Studies have shown that their concentration and distribution are influenced by factors such as economic development and population density in surrounding area[58]. In Asia, reported concentrations of microplastics river waters vary widely across literature.

Accurate assessment and quantification of microplastics depend heavily on sampling techniques, sample preparation protocols, and polymer identification protocols. However, the lack of standardized methodologies across these stages remains a major challenge, also for comparison of results from different studies. River water, being a vital source for drinking, agriculture, and aquatic ecosystems, directly affect human and environmental health, highlighting the urgency of addressing microplastic pollution.

Our review found a limited number of studies on microplastics in Asian rivers, with a disproportionate focus on China. There is a pressing need for more comprehensive research across other Asian countries to better understand the spatial and temporal distribution of microplastics and their potential impacts. Future studies should focus on diverse river regions and biotopes to assess contamination patterns more thoroughly.

A more detailed investigation into the sources, migration pathways, and transformation processes of microplastics is also necessary to evaluate their ecological and health risks. Furthermore, seasonal variation in the abundance should be examined using standard methods for sampling, sample preparation, and analysis. Current inconsistencies in sampling techniques (e.g., site selection, sample volume, collection tools), sample processing (e.g., filtration, digestion, separation), and analytical methods (e.g., microscopy, spectroscopy) contribute to significant uncertainties in reported microplastic concentrations.

Another critical gap is the inconsistent reporting on the absence of method recovery data, which affects the reliability of results. It is unclear whether the studies reviewed included recovery-corrected concentrations. Additionally, temporal variations microplastic abundance may result from changes in river flow rate and water volume, emphasizing the need for long-term monitoring.

Finally, there is a lack of impact assessments, particularly regarding the biological effects of microplastics on aquatic ecosystems. Future research should prioritize evaluating the ecological and toxicological consequences of microplastic pollution in the river systems to inform policy and management decisions in Asia and beyond.

Ethical statements

All subjects gave their informed consent for inclusion before they participated in the study.

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CRediT authorship contribution statement

Smriti Bastakoti: Data curation, Formal analysis, Investigation, Methodology, Visualization, Writing – original draft. **Nabin Adhikari:** Data curation, Formal analysis, Investigation, Methodology, Writing – review & editing. **Bhanu Bhakta Neupane:** Conceptualization, Supervision, Writing – review & editing. **Mohan B. Dangi:** Conceptualization, Funding acquisition, Supervision, Writing – review & editing. **Basant Giri:** Conceptualization, Data curation, Supervision, Visualization, Writing – review & editing

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Table 2: Overview of key parameters characterizing microplastics in river waters across Asia.

River name	Country	Sample collection year	Abundance (Mean ± SD) items/m^3	Shape	Color type	Size (mm)	Material type	Reference
Tuojiang	China	-	911.6 ± 199.7 to 3395.3 ± 707.2	Fiber*, film, foam, fragment	Black, multicolor, white*	<0.5, 0.5 – 1*, 1 – 2.5, 2.5 - 5	PP*, PE, PS, PVC	[31]
Wei	China	2017	3670 – 10700	Film, fiber*, foam, fragment, pellet	-	<0.5*, 0.5 – 1.0, 1. – 2.0, 2.0 – 3.0, 3.0 – 4.0, 4.0 – 5.0, >5.0	PE, PVC, PS	[59]
		2022	4670–12300	Fiber*, fragment, film	-	<0.5*, 0.5–1, 1–3, 3–5	PE*, PVC, PS, PP	[60]
Wei	China	2022	1033 - 8333	Fibers*, fragments* film, granule	Black*, white/transparent*	<0.5* 0.5—1, 1—5, 1—2, 2—5	PP*, PE, PS, PET and PVC	[61]
Wei River	China	-	2900–10300	Fiber*, debris*	-	-	PE*, PP* PET	[62]
Lijiang	China	-	0.13 – 1.50	Flake*, fiber, film, granule, line, string, foam	Colored*, white, Transparent, black	0.075 – 0.3, 0.3 – 1, 1 – 5*	PP/PE*, PP, PE, PB, PVC, PS, PA, Polyether sulfone	[63]
Qing	China	2019	170 ± 110 – 260 ± 200	Fragments*, fiber, films, pellets	-	Not reported	PE, EPR*, ABS, EPR, PE/PVA, PE/TPX, PS/PAC, PS/PE	[6]
Yulin	China	-	1.30	Fiber/line, film/fragment, pellet/foam*	-	<0.1*, 0.1 – 0.25, 0.25 – 0.5, 0.5 - 5	PE*, PP, PS	[52]
Haihe	China	-	0.69 – 74.95	Fiber*, fragment, film, foam, pellet	White*, transparent, black, brown/gray, blue/green, red	<0.05, 0.05 – 0.1, 0.1 – 0.5, 0.5 – 1, 1 – 2, 2 – 5	PE*, PE-PP, PA, PP, PS, PU, cellulose, PET	[34]
		2019	9200 ± 2200	Fiber/line*, fragment, film, pellet, foam	Black*, transparent, blue, green	<0.05, 0.05 – 0.1, 0.1 – 0.2, 0.2 – 0.5*, 0.5 – 1, 1 – 2, 2 – 5,	PE*, PP, cellulose, PS, PEs, PET	[64]
Manas	China	2019	14000 ± 2000 – 17000 ± 4000	Fiber*, fragment, film	White*, black, red, blur, transparent	<0.1, 0.1 – 0.3, 0.3 – 1.0*, 1.0 – 2.0, 2.0 – 5.0	PVC, PC	[65]
		-	21000 ±3000 – 49000±3000	Fiber*, fragment, films, foam, pellet	Black, white, red, blue, yellow, transparent	0.1-1.0*	PP, PET	[66]
Chishui	China	-	1770 to 14330	Fiber*, block, foam, film	White*, transparent, black, blue, green, red	<0.05, 0.05 – 0.5*, 0.5 - 1, 1 – 1.5, >1.5	PE*, PP, PS, PVC	[58]
Pearl (Xijiang river)	China	-	2.37 ± 0.70	Fragment, film*, fiber, foam, pellet	Black, colored, white, transparent	0.355 – 0.499*, 0.500 – 0.709, 0.710 – 2.799, 2.800 – 5.000	PS, PE*, PP, EVA	[67]
		2017	379 - 7924	Fiber*, fragment, film	White*, red, black, blue, yellow, green, and transparent	0.02–1*, 1–2	PP*, PE, PET	[68]
		2016 - 2017	570 ± 710	Sheet*, fragment, fiber, foam, spherule	White/ transparent*, red, blue, green, black	<0.25*, 0.25 – 0.45, 0.45 – 1.0. 1.0 – 5.0	PP*, PE, PET, PS, PVC, polyvinyl alcohol, PA/nylon, ethylene vinyl acetate, alkyd, PET, PS, PVA, PA, EVA, ABS, PC, PU, PMMA, PAN	[69]
		2022	290,000	-	-	0–0.03*, 0.03–0.050, 0.05–0.1, 0.1–0.2, 0.2–0.5	PET*, PUs, vinyl mq resin, PE, acrylates, PP, PVC	[70]
		2020	8140 ± 4530	Fragment*, fiber, film	Nonpigmented-transparent*, pigmented white, black, blue, green, red, yellow	0.01-0.1*, 0.1–1, 1–5	Polyolefin elastomer*, PET, PU acrylate, epoxy resin, phenol formaldehyde resin, silastic, PA, PE	[71]
		2020	545.4	Fiber*, Granule, fragment, film	Gray*, green*, white, transparent, black	<0.5*, 0.5–1, 1–2, 2–3, 3–5	PE*, PVC, PP, PS, ethylene/acrylic acid	[72]
		2020	294.6		White*, gray*, transparent, black, green			

Beijiang	China	-	0.56 ± 0.45	Foam, film*, fragment, fiber	Not reported	0.1-0.6, 0.6-2.0*, 2-5	PE, PP*, PS, PVC, PET	[45]
West	China	2019	2990 – 9870	Fiber, fragment, pellet, film	Not reported	<0.5*, 0.5 – 1.0, 1.0 – 5.0	PP*, PE, PS	[49]
Yangtze	China	2016	480 to 21520	Fiber*, fragments, granule	Not reported	<0.5*, 0.5 – 1, 1 – 2, 2 – 5	PEs*, PP, PE, PS	[73]
Pum Qu	China	-	63±18	Fiber*, Pellet	Blue*, black, red, white, transparent, purple	0.1 – 0.5, 0.5 – 1, 1 – 2, 2 – 3, 3 - 5	PE*, PP, PET, PS	[36]
Dafeng	China	2017	0.3-2.5	Fiber*, fragment, foam, film	White*	< 0.3, 0.3–0.5, 0.5–1,1–5	PET *, rayon*, Polybutylene terephthalate, polyoxymethylene, PS, polyethene	[74]
		2018	0.04-0.9					
Yongjiang	China	2018	500 - 7700	Fiber*, fragment, pellet, film	Blue*, green, red, purple, White and transparent	>0.3, 0.3–1*,1–3*	PE*, PET, Nylon, PP,	[75]
Qin	China	2018	0.1-5.6	Fiber*, line, sheet, fragment, foam	Black*, white, blue, green, red, yellow	<0.075, 0.075-0.3, 0.3-1,1-5*	PP*, PE, PET, PS, cellophane, PAN, PVA, nylon, LDPE	[76]
Qiantang	China	2020, 2021	1500–9400	Fragment*, fiber, sheet, foam	White*	0.05–0.2*, 0.2–1*, 1–3, 4–5	PET*, PVC, PP, PE, PS	[77]
Beijiang river	China	2019	3183	Fragment*, fiber, film, sphere	White*, yellow, blue, black, red, green	< 0.5*, 0.5-1, 1-2, 2-3, 3-4, 4-5	-	[78]
Pearl river			7571					
Yellow	China	-	497000 – 930000	Fragment, fiber*, particles	-	<0.2*, 0.2 – 0.5, 0.5 - 5	PE, PP, PS	[79]
		2021	2510830 ± 2971270	-	-	0.02–0.05* 0.05–0.1, 0.1–0.2, 0.2–0.5	PBS*, PET*, PP carbonate, PS, PA, PE, PP, PU, Polybutylene adipate-*co*-terephthalate, PVC, PC, polymethyl methacrylates, poly tetra fluoroethylene	[33]
		2021	432500 ± 240540				PP *, PBS, PC, PET, PA, PE, PS, PU, PVC, PC, polymethyl methacrylates, poly tetra fluoroethylene, polyacrylamide, polyvinyl alcohol, PBadipate-*co*-terephthalate	
Yellow	China	2023	6,400 ± 3,400	Fiber*, particles, fragments, and films	transparent, gray, black*, red, yellow, blue, green, and purple.	<0.1, 0.1–0.2, 0.2–0.5, 0.5–1*, 1–2*, 2–3, 3–4, 4–5	PET*, PA, PP, PE, PS, PVC, PVA, PAN, PVS, EVA	[80]
Songhua	China	2019	6670 - 160000	Line*, fiber* flake, granule, film, foam	White*, blue, red, transparent, green, yellow, gray, black, and purple	0.05-0.2, 0.2-0.5,0.5-1*, 1-2, 2-5	PE*, PP, PS, PET, PA	[81]
Yulong	China	2020	0–4000	Fiber*, film, fragment	Blue*, white, black, red	0.05-0.5*	PP, PS, and PET	[82]
Southern Jiangsu Canal	China	2021	9590 ± 3950	Fragment*, bead, fiber, pellet, film	colorless or white*	<0.1*, 0.10–0.25, 0.25–0.50, 0.50–1.00, >1.00	PET*, PC, PE, chlorinated PE, PU	[83]
Meishe river	China	2021	3000–10000	Fiber*, fragment, film	White*, black, transparent,	<0.1, 0.1–0.5*,0.5–1, 1.0–5.0	PE*, poly octadecyl acrylate, PP, cellophane, poly decyl methacrylate, PET, PS	[84]
Dagu river	China	2019	680-3960	Fiber*, foam, fragment	Colorless*, red, black, blue	0.06 – 0.1, 0.1 – 0.5*, 0.5 – 1, 1 –2, >2	PP*, PE*, PVC*, PS, PET, acrylonitrile-butadiene-sty-rene copolymer, PA, PC, polyether plastics	[85]

Lhasa River	China	2019	630	Film*, fiber, fragments, pellet, foam	Transparent *, black, blue, green, red, yellow	0–0.5*, 0.5-1, 1-2, 2-3, 3-4, 4-5	PP*, PE*, PA, PVC, PS	[86]
Songhua river	China	-	4020	Fiber*, debris, pellet, film, foam	Yellow*, white, red, transparent	<0.5*, 0.5-1, 1-2, 2-3, 3-5	PE*, PET, PS, PP, high-density PE, PVC, PU	[87]
Fengshan	Taiwan	2018	334 – 1058	Fiber*, fragment	Not reported	0.05 – 0.297*, 0.297 – 5.0	PE*, PET, PA, PEs, PU, polyvinyl alcohol, Phenolic resin	[88]
Maozhou	Hongkong	2019	3500±1000 – 10500±2500	Fragment*, film, fiber, foam	White, black, yellow, blue, transparent*	0.01 – 0.1*, 0.1 – 1.0, 1.0 – 5.0	PE*, PP, PS, PVC	[89]
Chao Phraya	Thailand	2018	104	Fibers, fragments*, pellets, films	White, transparent, blue, green	0.053 – 0.5*, 0.5 – 1.0, 1.0 – 5.0	PP*, PE, PS, PEs, cellophane, EVA, polytetrafluoroethylene	[46]
		2019	48 ± 8	Fragment*, pellet, fiber, film	Green, blue, red, yellow, white*, transparent,	0.05 – 0.3*, 0.3 – 0.5, 0.5 – 1.0, 1.0 – 5.0	PP*, PE, PS, PEs, PU, PB	[90]
Tapi-Phumduang	Thailand	2019	1770±280	Fibers*, fragments	Black*, blue, white, green, red	<1*, 1 – 5	Rayon*, PP, PE, PET, nylon	[41]
Chi river Pong river	Thailand	2019	141	Fiber*, fragment, pellet, foam	Dark blue*, white, black, purple, blue, red, pink, green, yellow	1.001–2*, 0.051–0.25, 0.251–0.5, 2.001–5	PP*, PVC, PE, acetate fiber, and PEs	[91]
Ganga	India	-	0.380 to 0.684	Fibers, film*, foam, fragments	Black, blue, brown, White*, transparent, others	<1, 1 – 2.5, 2.5–5*, >5	PE*, PS, PVC, PE, PEs, cellophane	[92]
		2022	2800000–4200000	Fiber*, film, fragment, pallet	Black*, green, red, blue, yellow, orange, purple, and brown	-	PE*, propylene, PVC, PS, PA, PVC, PET, PU	[32]
Ganga	India	-	17000-36000	films, foams, fragments, and filaments	white, brown, blue,	-	PET, rayon, polyester, PV	[93]
Cooum river	India	-	89 in total	Fiber*, bed, pellet	Colored*, colorless	<1*, 1-3, 3-5	not reported	[94]
	India	-	20000-50000	Fiber *, film, pellets, fragments, beads, foam.	Transparent*	<1*	PET*, PP*	[95]
Brahmapu tra River	India	2022	0.14 ± 0.11	Fiber*, fragment, and film	Blue*, black*, and red*, amber, yellow, and green	1.056 ± 1.021	nylon, PE*, PP, and isotactic polypropylene (iPP)	([96])
Periyar River	India	-	122890	Fiber, fragment and filament	-	-	PE, PP	[97]
Thamirabarani River	India	-	27730 ± 2290	Fiber*, fragment, foam, pellet	red*, transparent, black, white, blue, green, yellow	<0.5 0.5–1, 1–2, 2–3*, 3–4, and 4–5	PE, PP, blended polyethylene-polypropylene (PE-PP), PA, PU	[98]
River Gomti	India	-	4200-8380	-	-	-	PE*, PP*	[99]
Arakawa	Japan	2019 - 2020	1.8	-	-	0.5 – 1, 1 – 2*, 2 – 3, 3 – 4, 4 – 5	PE*, PP, PS	[100]
Arakawa River	Japan	2020 & 2021	2.21 ± 1.48	-	-	0.5–1	PE*, PP, PS	[101]
Umeda river	Japan	-	600-2500	Flake*, filament, fragment, spherule		0.075-0.3,0.3-5*	PE*, PVC, PP	[102]
Citarum	Indonesia	-	0.0574 ± 0.025	Fragment*, fiber	Blue*, black, transparent	0.3-0.5, 1–5*	PE*, PP	[103]
Surabaya	Indonesia	2019	1.5 – 43.1	Film*, fragments, foam, pellet, fiber	Transparent*, white, blue, red, black, yellow	0.3 - 5	PE*, PP, PS, PET	[50]
Cisadane river	Indonesia	-	13.33 - 113.33	Fragment*, foam, fiber, granules	not reported	<0.3, 0.3-0.5, 0.5-1*, >1	PE*, PS*, PP*, PU, PET, cellulose acetate group, nylon 6/9, PA, PEs	[104]

Tallo river	Indonesia	2019	0.74 ± 0.46 to 3.41 ± 0.13	Fragment*, line, film, pellet	Blue*, transparent, white, red, green, black	larger MPs*, Smaller MPs	PE*, PP, Poly(styrene:butadiene)	[105]
Pekalongan River	Indonesia	-	45200 - 99100	Fragment*, film, pallet, fiber, foam	Black*, blue, green, red, transparent, yellow	0.3-1, <0.1*, 1-2, 2-3, 4-5	PS, PEs, PA	[106]
Metro river	Indonesia	2022	73550	Fragment*, fiber, soft film, pellet	Clear*, blue, yellow, red, grey, white, green, orange, black, mixed	0.001-1*,1-5	-	[107]
Cisadane River	Indonesia	-	1.6 - 36.0	Fragment*, fiber	Transparent *, blue, brown, cream, red, black,	0.065- 4.932 fragment 0.023 - 2.444 fiber	PET, PP	[108]
Mahakam River	Indonesia	-	19200 ± 1800 to 58500 ± 3500	Fragments* pellets, fibers, films, and foams	yellow, green, red, blue, black, and transparent*	>1*, 1 to 2, 2 to 3, 3 to 4, and 4 to 5	PE*, PP*,	[109]
Karang Mumus River	Indonesia	2023	3610 ± 1200	Fiber Fragment Film Bead			PE*, PS, nylon, olefin fiber, PP	[110]
Klang	Malaysia	2019	500 – 4500	Fiber*, fragment, pellets	Transparent*, black, red, blue	< 0.3, 0.3 – 1.0*, >1.0	PA*, PE	[111]
Kelantan river	Malaysia	-	179600	Fiber*, fragment, film, pellet	Transparent*, red, green, orange, brown, yellow, purple, pink	<0.3, 0.3-0.5, 0.5-1, 1-5	PP, PE, PET, nylon, phenoxy resins, poly(methyl acrylate), poly(methyl methacrylate), PS, polytetr afluoroethylene, PU, rayon	[112]
Langat river			1464800		Transparent*, red, green, orange, brown, yellow, purple	<0.3, 0.3-0.5, 0.5-1, 1-5*		
Kemena river	Malaysia	-	60000 - 128000	Fiber*, film, foam, fragment	Blue*, pink, yellow, black, transparent	0.1 – 1*, 1-2, 2-3. 3-4, 4-5	PE, PS, PC, PET	[113]
Niah river								
Nakdong	South Korea	2017	293 ± 83 to 4760 ± 5242	Fragment*, fibers, spheres, films	-	<0.3*, 0.3 – 1, 1 - 5	PP*, PEs, PE, PA, PS, alkyd, acrylic, poly(EVA), PU, PVC, poly(acrylate-styrene)	[18]
Han	South Korea	2018	7.0 ± 12.9 (surface)	Fragment*, fiber	-	0.1 – 0.3*, 0.3 – 0.6, 0.6 – 1, 1 - 5	PE, silicone*, PS, PP, PEs, PU, polytetrafluoroethylene, rayon, PVC, nylon, acrylic, polyolefin	[35]
			102.0 ± 50.3 (depth=2m)					
Arun	Nepal	-	142 ± 63	Fibers*, Pellet	Blue*, black, red, white, transparent, purple	0.1 – 0.5, 0.5 – 1, 1 – 2, 2 – 3, 3 - 5	PE*, PP, PET, PS	[36]
Sunkoshi	Nepal	-	308 ± 14	Fiber*, pellet	Blue*, black, red, white, transparent, purple	0.1 – 0.5, 0.5 – 1, 1 – 2, 2 – 3, 3 - 5	PE*, PP, PET, PS	[36]
Tamor	Nepal	-	233 ± 38	Fibers*, Pellet	Blue*, black, red, white, transparent, purple	0.1 – 0.5, 0.5 – 1, 1 – 2, 2 – 3, 3 - 5	PE*, PP, PET PS	[36]
Saptakoshi	Nepal	-	225 ± 141	Fibers*, Pellet	Blue*, black, red, white, transparent, purple	0.1 – 0.5, 0.5 – 1, 1 – 2, 2 – 3, 3 - 5	PE*, PP, PET PS	[36]
Saptagandaki	Nepal	2022	61,200 ± 27800	Fragment*, Pellet, fiber	Blue*, transparent, black, red	0.03-0.1*, 0.1-0.2, 0.25-0.5	PET*, Cellophane, PE, PVC	[114]
		2022-2023	24,700 ± 10800					
Buriganga	Bangladesh	2021	4,330 ± 580 - 43,670 ± 580	Fragment*, fiber, Foam, pellet, and film	Red*, transparent, blue, green, white, black, yellow	0.3–1,1–3*, 3-5	PP*, PE, PS, PVC, PET, PA	[115]
		-	250000 - 117000	Fiber, fragment*, foam, film, pellet	Blue*, pink, transparent, red, violet, black	<0.5*, 0.5-1, 1-5	PET*, EVA, High-density PE, Acrylonitrile butadiene styrene, Cellulose acetate*, Nylon	[116]

Karnafully	Bangladesh	2020	570 ± 70 - 6.63 ± 520	Fiber*, fragment, film, pellet	Blue*, transparent/white, black, red, green	<1*, 1-5	PE*, PET, PP, PA (Nylon), rayon	[117]
Karnaphuli	Bangladesh	2019	120111 items/km^2	Fiber or thread*, fragment, foam, film, pellet, microbead	Black*, purple, white, blue, green, translucent, red, pink, brown	0.3-0.5 *,0.5 - 1, 1 - 5	PET*, PA, PE, PS, alkyd resin, cellophane, polyvinylidene fluoride, polyether urethane	[118]
		2020	152222 items/km^2					
		2020	164444 items/km^2					
Lower Ganges River	Bangladesh	-	10,670 - 20,330	-	-	-	EVA, PS, PP, PE, and nylon	[119]
Surma River	Bangladesh	-	37330–686670	fibers, fragments, and microbeads	-	<0.2*	PE*, PA, PP, Cellulose acetate (CA), PET, and PS	[120]
Surma River	Bangladesh	-	12330 ± 2980	Fiber*	Black*, transparent	1–2*	-	[121]
Aras river	Iran	2021	12.8 ± 10.5	Fiber*, fragment, film, foam	Black*, white, gray, brown, blue, transparent, red, green, yellow	0.1-1, 1-2*, 2-3, 3-4*, 4-5	PE*, PA, cellophane, PS	[122]
Mekong river Delta (Tien River)	Vietnam	2019	53.8 ± 140.7	Fiber*, fragment, microbeads, pellets, films, foams	Blue*, red, white, green, yellow, and grey	-	PE*, PP, PEs	[123]
Mekong River	Cambodia and Vietnam	2019	24	Fiber *, fragments, film	-	-	PET*, PP, PE	[124]
Ravi	Pakistan	2020 & 2019	768 ± 869	Fiber*, fragments, film, sheet, foam, beads	Transparent*, black, brown	0.05-1.5, 1.5-3, 3-5*	PP*, PE*, PEs, PS	[125]
			1324 ± 1925					
		2021	66000	Fiber*, fragment, sheet, cube	not reported	not reported	PVC*, PS, PP, PE	[126]
Swat river	Pakistan	2021	305.79 ± 289.66	Fiber*, foam, fragment, sheet	not reported	0.3*, 0.150, 0.05	not reported	[127]

* Most abundant
PVC- Polyvinyl chloride
PP- Polypropylene
PET- Polyethylene terephthalate
PS- Polystyrene
PE- Polyethylene
PA- Polyamide
PU- Polyurethane
PC- Polycarbonate
PB- Polybutylene
PBS- Polybutylene succinate
PEs- Polyester
EVA- Ethylene-vinyl acetate

A systematic review of microplastic pollution in rivers across Asia

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Supplementary information

List of Papers Included for Review

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