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Distribution Characteristics and Ecological Risk Assessment of Microplastic Pollution in the Water Body of Dasha River in Jiaozuo City

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Abstract: Microplastic is one of the new pollutants, with a wide range of sources and distributions, and it can also be used as a carrier to adsorb heavy metals, persistent organic pollutants, and other hazardous substances in the environment, which constitutes a potential threat to the health of biological human beings. However, there is only one study on microplastic water pollution in Jiaozuo City, Qin River. In this study, 19 sampling stations in Dasha River in Jiaozuo City were sampled in March 2025, and microplastic abundance, shape, color, and particle size were analyzed by body-view microscopy, and the results showed that microplastics were detected at 100% in all sampling stations, with an abundance range of 0.9-10.6 n-L-1 and an average abundance of 3.90 ± 2.83 n-L The average abundance was 3.90 ± 2.83 n-L-1. Fibers were the main form of microplastics in the Dasha River, with black and transparent colors and particle sizes ranging from 0.3 to 1.0 mm. The polymer types were further identified with the help of micro Fourier transform infrared (FTIR) instrument, and it was found that polyethylene terephthalate (PEGT), polyamide, and polypropylene were the main microplastic species in the study area. The results of the ecological risk assessment showed that the microplastic pollution load of the Dasha River in Jiaozuo City was at low risk (level I), while the polymer risk index of the sampling stations with high hazard scores of PVC and PAN was high, and even reached very high risk in the S19 sampling station. The results of this study can provide a reference for Jiaozuo City to recognize the microplastic pollution situation in rivers and to prevent and control the risk.

Keywords: Microplastics; Jiaozuo City; Dasha River; Distribution characteristics; Risk assessment.

1. Introduction

Amidst the increasing complexity and severity of global ecological and environmental issues, the emergence and spread of emerging contaminants are gradually becoming a critical challenge that urgently needs to be addressed in the process of global sustainable development[1]. UNESCO provides a broad definition of emerging contaminants as any synthetic or naturally occurring chemical substance or microorganism that is not commonly monitored or effectively managed in the environment and has the potential to cause known or suspected adverse ecological and human health effects [2]. These contaminants extensively cover numerous chemical substances involved in daily life and industrial production, such as pharmaceuticals, personal care products, pesticides, industrial and household chemicals, metals, surfactants, industrial additives, and solvents [3, 4]. Currently, the international community is widely focusing on four main categories of emerging contaminants: persistent organic pollutants (POPs), endocrine-disrupting chemicals (EDCs), antibiotics, and microplastics. Microplastics, due to their unique properties and widespread distribution, have become a global focus of concern.

Microplastics are generally defined as plastic particles smaller than 5 mm in size. They have a wide range of sources and are extensively distributed, having been found in rivers, lakes[5], oceans, soils, the atmosphere, and even polar regions [6]. Furthermore, microplastics have multifaceted negative impacts on ecosystems. They can enter organisms through pathways such as ingestion, affecting normal feeding and nutrient absorption. Additionally, the surfaces of microplastics can adsorb harmful substances present in the environment, such as heavy metals and persistent organic pollutants. Through food chain transfer and biomagnification, these substances can accumulate continuously in organisms at higher trophic levels, posing potential threats to biodiversity, ecosystem services, and human health [7, 8]. Therefore, investigating microplastics in environmental media and understanding their pollution levels is particularly crucial.

Jiaozuo City, as a traditional industrial city, has a history where the DaSha River long bore the pressure of industrial wastewater and domestic sewage discharge, leading to severe water quality deterioration. By the end of the "12th Five-Year Plan" period, the water quality in some sections had even deteriorated to Class V+ (inferior to Class V). Although a series of subsequent treatment measures have been implemented, resulting in improved water quality, the pollution issue of microplastics, as an emerging contaminant, has begun to emerge in the DaSha River due to the rapid increase in the usage of plastic products. Moreover, the unique geographical location and hydrological conditions of the DaSha River render it a key area for the migration and accumulation of microplastics. In early 2023, the Henan Provincial Peoples Government issued the "Henan Province New Pollutants Control Work Plan" and the "Henan Province Strengthening the Supervision and Management of Sewage Outlets into Rivers Work Plan," which designated microplastics as a key emerging contaminant of concern and explicitly included the DaSha River in the list of major rivers and key lakes and reservoirs for conducting environmental health risk assessments. However, research on microplastic pollution in the DaSha River is currently almost nonexistent, and there is a lack of scientific understanding regarding its pollution status in different river sections and its potential risks to the ecosystem. Therefore, this study aims to investigate the distribution characteristics of microplastic pollution in the water body of the DaSha River and the potential environmental risks it may pose, with the goal of providing a reference for microplastic pollution research and prevention/control efforts.

2. Materials and Methods

2.1. Sample collection

In accordance with the specifications of the Technical Specification for Surface Water Environmental Quality Monitoring (HJ 91.2-2022) and based on field investigations, 16 sampling stations were established in the DaSha River in Jiaozuo City in March 2025, taking into account factors such as river length, river conditions, and sampling difficulty. The sampling stations were numbered sequentially from upstream to downstream and were divided into four sections: upstream (S1–S2), mid-upper reaches (S3–S7), mid-lower reaches (S8–S12), and lower reaches (S13–S16)[9], as shown in Fig. 1. During the sampling period, stations S1 to S3 were dry and contained no water. At each sampling station, 20 L of surface river water was collected using a stainless steel bucket and a Plexiglas water sampler. The samples were sealed with aluminum foil and transported to the laboratory for analysis. To ensure data accuracy, the sampler and sample bottles were rinsed three times with the water sample prior to collection.

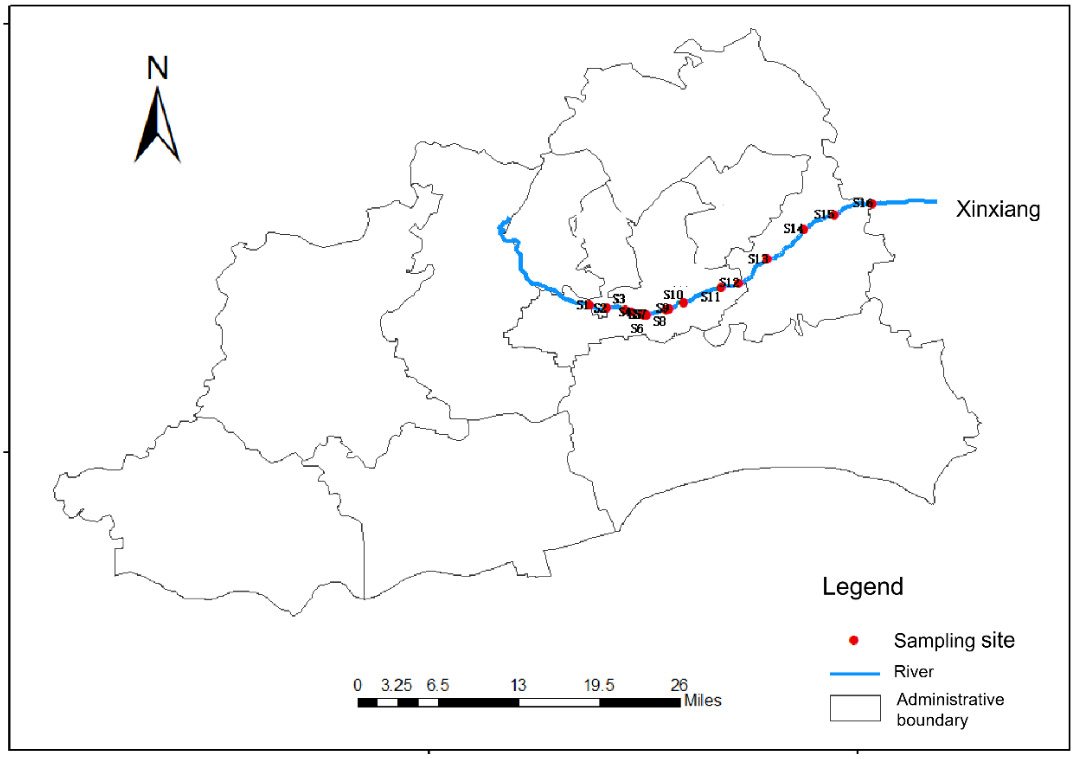

Fig. 1 Distribution of sampling stations in the DaSha River, Jiaozuo City

2.2. Sample processing

Large impurities (such as coarse gravel, aquatic plants, and leaves) were removed from the collected water samples using tweezers cleaned with ultrapure water. The water was then filtered through a 5 mm stainless steel sieve to remove plastics larger than 5 mm. Subsequently, the water sample was vacuum-filtered through a 47 mm diameter glass fiber filter membrane with a pore size of 45 μm. The retained material on the sieve was rinsed into a 1 L beaker using a wash bottle filled with ultrapure water. Then, 20 mL of 30% H_2O_2 solution was added to the beaker. The beaker was sealed with aluminum foil to prevent contamination from airborne fibers. The mixture was then agitated in a constant temperature oscillator at 60°C and 100 r/min for 72 hours. After the reaction, no biological residues were observed, indicating complete digestion[10]. Subsequently, 200 mL of NaCl saturated solution (density approximately 1.20 g/cm^3) was added to the solution. The mixture was stirred for 3 minutes and then allowed to stand for 24 hours. After standing, the supernatant was transferred and vacuum-filtered through a 47 mm diameter glass fiber filter membrane with a pore size of 45 μm. The filter apparatus walls were rinsed with ultrawater to ensure complete transfer of the sample onto the filter membrane. (The residue was subjected to the NaCl addition and the above procedure repeated three times.) The filter membrane was then transferred from the filtration apparatus to a clean Petri dish using tweezers. The Petri dish was labeled with sample information, dried at constant temperature, and stored for subsequent analysis[11].

2.3. Sample analysis and identification

Qualitative analysis of microplastics on the filter membranes was conducted using a stereomicroscope. The color, particle size, and morphology of the particles were observed and recorded photographically. Suspected microplastic particles were selected and identified using a micro-Fourier Transform Infrared Spectrometer (μ-FTIR) in transmission mode. The mid-infrared range (4000–400 cm^{-1}) was employed with a resolution of 4 cm^{-1}, and 10 scans were performed for each particle[12]. The acquired spectra were compared with reference spectra in the database to determine the polymer type of the microplastics. Microplastics with a matching degree higher than 60% were recorded as the corresponding material. Based on these results, the microplastic abundance was statistically calculated.

2.4. Risk assessment

In recent years, assessing the potential ecological risks of microplastics has become an important component of research on the current status of microplastic pollution[13]. However, as a unified and standardized ecological risk assessment model has not yet been established, current studies primarily refer to assessment methods used for other pollutants to evaluate the potential ecological risks of microplastics.

(1) Microplastic pollution load index (PLI)

This index is used to determine the degree of hazard posed to the environment by microplastics detected in water and sediment[14].

$$CF_i = {}^{C_i}/_{C_{oi}}$$

$$PLI = \sqrt{CF_i}$$

In the formula, CFi is the contamination factor of microplastics; Ciis the measured concentration of microplastics at a specific sampling site (n/L); Coiis the background value,i.e., the abundance of microplastics under unpolluted conditions; PLI is the pollution load index of microplastics at a given site; and n is the number of sampling sites.

(2) Microplastic polymer hazard index (HI). This index uses the types of microplastic polymers and their polymer hazard scores as indicators for assessing microplastic risk. It is used to determine the chemical toxicity hazard scores of different types of microplastic polymers to the ecological environment[15].

$$HI = \sum P_n \times S_n$$

In the formula: HI represents the microplastic polymer hazard index;Pnis the percentage of different microplastic polymer types at the sampling site; Sn is the hazard score of the constituent microplastic polymers[16](see Table 1).

Based on the values of PLI and HI, the ecological risk levels of microplastics were ultimately classified[17]as shown in Table 2.

Table 1. Hazard scores of microplastic polymers

Polymer type	**Abbreviation**	**Hazard score**
Polypropylene	PP	1
Polyethylene terephthalate	PET	4
Polyethylene	PE	11
Polystyrene	PS	30
Polyamide	PA	47
Polyvinyl chloride	PVC	10551
Polyacrylonitrile	PAN	10599
Polycarbonate	PC	1177
Polymethyl methacrylate	PMMA	1021
Acrylonitrile butadiene styrene	ABS	6552
Polyurethane	PU	7384
Ethylene-vinyl acetate copolymer	EVA	9
Polybutadiene	PB	6

Table 2. Classification of microplastic risk assessment levels

Risk level	Low	Medium	High	Extremely high
PLI	<10	10-20	20-30	>30
HI	<10	10-100	100-1000	>1000

2.5. Quality control

To ensure the accuracy and reliability of the experimental results, laboratory personnel wore cotton clothing throughout the sampling, processing, and analysis procedures. All experimental utensils were meticulously cleaned and rinsed with ultrapure water at least three times. During the experiment, three sets of blank controls were conducted throughout the entire process, and no microplastics were detected on the filter papers of the blank samples.

2.6. Data processing

Microsoft Excel 2021 was used for statistical processing of the color, shape, particle size, polymer type, and abundance of microplastics at different sampling stations. ArcGIS 10.8 was employed to map the distribution of sampling stations, and Origin 2024 was used to generate spatial distribution maps of microplastic abundance, particle size, color, and polymer type.

3. Results and Analysis

3.1. Microplastic abundance

In this study, the unit for microplastic abundance in the water samples was "$n\cdot L^{-1}$". Microplastics were detected in all 19 sampling stations, with a detection rate of 100% (Fig. 2). The abundance ranged from 0.9 to 10.6 $n\cdot L^{-1}$, with an average abundance of 3.90 ± 2.83 $n\cdot L^{-1}$. This value is lower than that of the Wuding River (2.5–35.63 $n\cdot L^{-1}$), the Weihe River in Northwest China (3.67–10.7 $n\cdot L^{-1}$)[18], and the Guangzhou section of the Pearl River (8.9 $n\cdot L^{-1}$)[19].

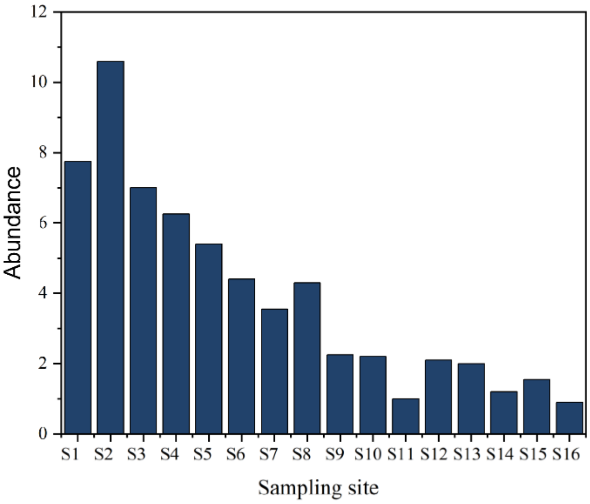

Fig. 2 Microplastic abundance at each sampling site in the DaSha River

Overall, the microplastic abundance in the DaSha River in Jiaozuo City exhibited a trend of upstream (9.18 (7.75–10.6) $n\cdot L^{-1}$, n=2, range shown due to small sample size) > mid-upper reaches (5.32 ± 1.39 $n\cdot L^{-1}$) > mid-lower reaches (2.37 ± 1.20 $n\cdot L^{-1}$) > lower reaches (1.41 ± 0.47 $n\cdot L^{-1}$). The lower abundance at S11, located in the mid-lower reaches, compared to the lower reaches, may be attributed to its location between Zhongyuan Road and the Jianggou River confluence, where extensive agricultural land along this section provides fewer microplastic sources compared to the rural residential agglomerations in the lower reaches. This finding contradicts the results from the Xiangxi River, which showed an order of midstream > downstream > upstream. The main reason for this discrepancy may be that the upstream of the DaSha River dries up during the dry season, resulting in low water volume at sampling sites S1 and S2.

Spatially, the distribution of microplastic abundance at different sampling sites in the DaSha River was uneven. The highest abundance was observed at site S2, while the lowest was at site S16. This result may be related to factors such as population density, human activities, and tributary inflows. The highest abundance at site S2, located downstream of the Xingfu River confluence, may be attributed to the numerous anglers and visitors in the surrounding area. Abrasion or disposal of fishing gear and daily plastic products brought by tourists, as well as inputs from the Xingfu River tributary, may contribute to the high microplastic abundance at this site.Site S16, situated at the outlet section of the DaSha River in Jiaozuo City, is far from residential areas and has fewer pollution sources.Additionally, it was found that sites S3, S6, and S8, which are located upstream of the dam, exhibited higher abundances than their downstream counterparts (Fig. 3). This finding is consistent with the results of studies by Wu Fengxue and Sun Tianyi, which demonstrated that dams have an accumulating effect on microplastics.

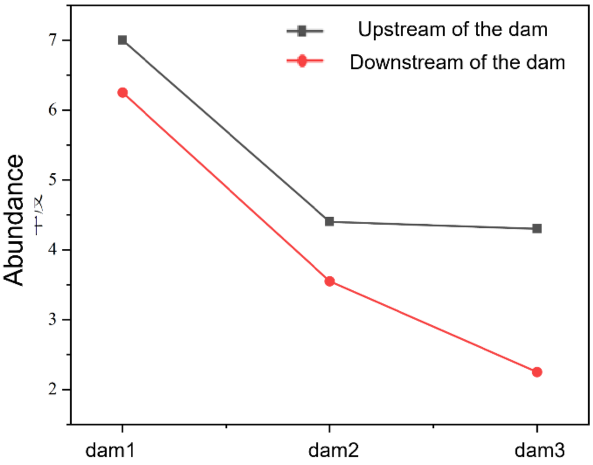

Fig. 3 Microplastic abundance upstream and downstream of the dam in the DaSha River

3.2. Microplastic shapes

Based on actual observation, the microplastics collected from the surface water of the DaSha River in Jiaozuo City were classified into four shapes: fibers, fragments, films, and granules. The proportion of each microplastic shape at every sampling site is shown in Fig. 4. When analyzing all microplastics collected from the study area as a whole, it was found that fibrous microplastics were the dominant shape in the DaSha River, accounting for 82.43%. This finding is consistent with the results of studies on rivers in Tongzhou District, Beijing (90.23%), the surface water of the Yangtze River Estuary[20](79.7%), and the water body of the Handan section of the Zhanghe River (75.9%–77.4%). The reasons for this phenomenon may be attributed to the widespread production and use of synthetic fibers[21]as well as the discharge of wastewater from sewage treatment plants[22].Fragments and granules were the next most prevalent shapes, accounting for 13.22% and 2.98%, respectively, while films constituted only 1.37% of all microplastics. At different sampling sites, fibers and fragments were detected in all samples, with proportions ranging from 68.57% to 94.44% and 4.76% to 26.42%, respectively. Granules and films were detected only at some sites. The highest proportion of granules was observed at site S7, which may be because S7 is located downstream of a dam and near the sandy beach of the DaSha River in Jiaozuo. Direct human activities introduce substantial amounts of plastic waste, which is decomposed into granules by environmental processes. These granules then become trapped and accumulate in the beach area due to the influence of hydrodynamics and topography, which hinder their dispersion. Additionally, the dam slows down the flow velocity in the reservoir area, reducing hydrodynamic forces and decreasing the waters carrying capacity. As a result, granular microplastics that would otherwise move rapidly with the flow tend to settle and become trapped in the area behind the dam. The highest proportion of films was observed at site S12, which is located downstream of the confluence of the Jianggou tributary. The Jianggou area is surrounded by extensive agricultural land with numerous greenhouses, which may account for the high film content at this site.

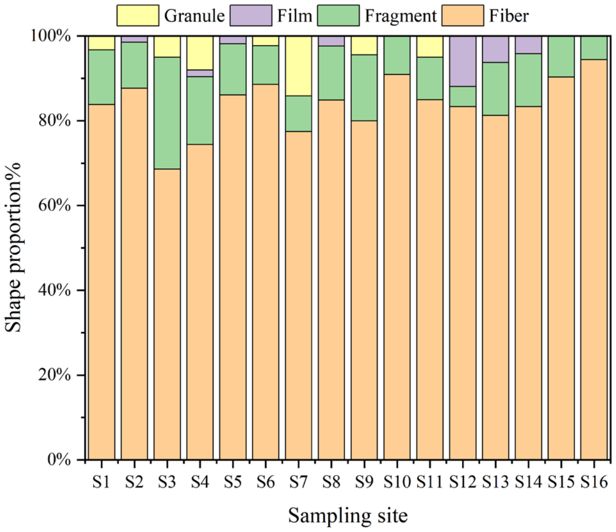

Fig. 4 Proportion of microplastic shapes in the DaSha River

3.3. Microplastic colors

The microplastics in the surface water exhibited a diverse range of colors. Based on microscopic observation, they were classified into eight categories: transparent, white, yellow, green, red, black, blue, and other colors. The distribution results are shown in Fig. 5. During the production of plastic products, various colorants are added to enhance their appeal; therefore, the diversity of microplastic colors indicates the wide range of sources of microplastics in the environment. The microplastics in the DaSha River were predominantly black (24.2%) and transparent (21.8%). This may be attributed to the high production volume of black plastics in daily industrial and domestic applications due to their light-shielding properties and low cost. Additionally, the carbon black in black plastics can absorb ultraviolet radiation, inhibiting photo-oxidative degradation and leading to their long-term persistence and accumulation in water bodies. Transparent microplastics may originate from transparent plastic products such as plastic bags, nylon nets, and agricultural films, and may also result from the weathering and fading of other colored microplastics. The observed presence of colors such as red and blue, along with faded white appearances, also indirectly suggests that microplastics have undergone fading due to prolonged exposure in the environment.

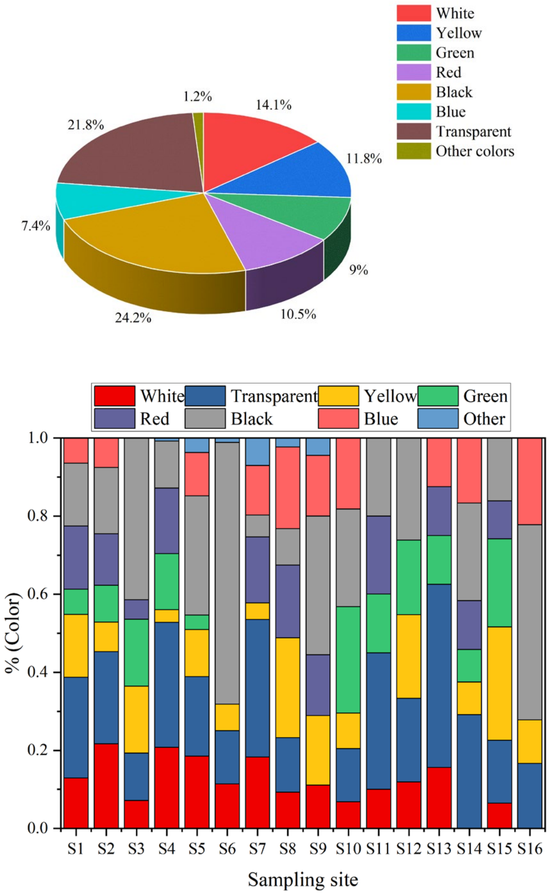

Fig. 5 Proportion of microplastic colors in the DaSha River

3.4. Microplastic particle sizes

In this study, the particle sizes of microplastics were classified into five categories: <0.1 mm, 0.1–0.3 mm, 0.3–1 mm, 1–2 mm, and 2–5 mm. As shown in Fig. 6, the microplastics in the aquatic environment of the DaSha River were predominantly small in size, with most particles concentrated in the 0.3–1.0 mm range. This finding is consistent with the results of studies conducted in the Lanzhou section of the Yellow River and Jiangsu coastal fishery waters. This phenomenon may be attributed to the fact that smaller microplastics are more likely to float on the water surface and are thus more easily collected, resulting in a higher proportion of small-sized microplastics in the samples. Furthermore, during environmental transport, large plastic or microplastic particles may be gradually decomposed or fragmented into smaller microplastic particles due to external factors such as hydraulic action, photoaging, or biodegradation. It is noteworthy that previous studies have shown that smaller microplastics are more readily ingested by aquatic organisms and can be transferred and accumulated through the food chain, potentially leading to more severe ecological and environmental impacts.

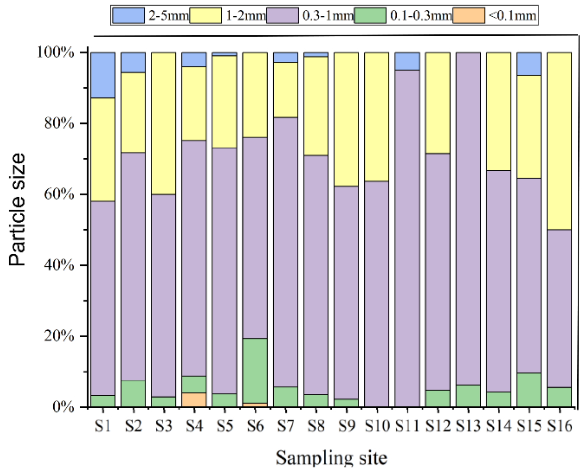

Fig. 6 Proportion of microplastic particle sizes in the DaSha River

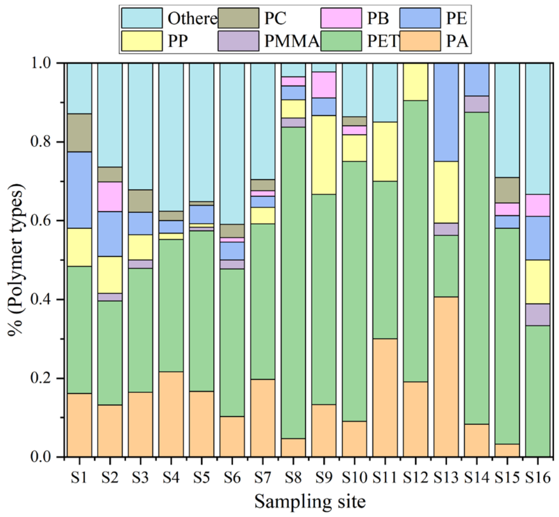

Fig. 7 Schematic diagram of the distribution of microplastic polymer types

3.5. Microplastic polymer types

In this study, a micro-Fourier Transform Infrared Spectrometer (micro-FTIR) was used to identify the polymer composition of suspected microplastic particles. A wide variety of microplastic types were detected in the DaSha River in Jiaozuo City. The main polymer types identified included 23 plastic types, such as polypropylene (PP), polyethylene terephthalate (PET), polyethylene (PE), polystyrene (PS), polyamide (PA), polyvinyl chloride (PVC), polyacrylonitrile (PAN), polycarbonate (PC), polymethyl methacrylate (PMMA), and acrylonitrile butadiene styrene (ABS). To facilitate the statistical analysis and description of the characteristics of the microplastic types, the detected polymers were categorized into the top seven types and "others" based on their abundance proportions, as shown in Fig. 7. Among these, PET, PA, and PP were the predominant polymer types. PET is the most widely used plastic raw material in engineering, textiles, and containers, commonly found in beverage bottles, textile fibers, and packaging materials. Its high proportion may originate from the packaging films, water bottles, and clothing fabrics of surrounding residents, which is generally consistent with the earlier finding that microplastics were predominantly fibrous in shape. PP is a commonly used raw material in industry and manufacturing due to its excellent properties, such as wear resistance, easy moldability, and light weight. It is widely used in industrial applications, as well as in the automotive industry, pharmaceutical sector, and food packaging. PA possesses the advantages of high strength, wear resistance, and oil resistance, and is primarily used in clothing fabrics, fishing nets, ropes, automotive parts, and food packaging films.

4. Ecological Risk Assessment

In this study, two indices, namely the Pollution Load Index (PLI) and the Polymer Hazard Index (HI), were employed to evaluate the potential pollution risk of microplastics in the surface water system of the DaSha River. The results showed that the overall microplastic pollution load index ranged from 1 to 3.43, with the maximum value observed at sampling site S5 (Fig. 8). The risk level for all sites was Class I, indicating a low level of microplastic pollution. The PLI values were positively correlated with microplastic abundance; therefore, the factors influencing the PLI values were consistent with those affecting microplastic abundance.

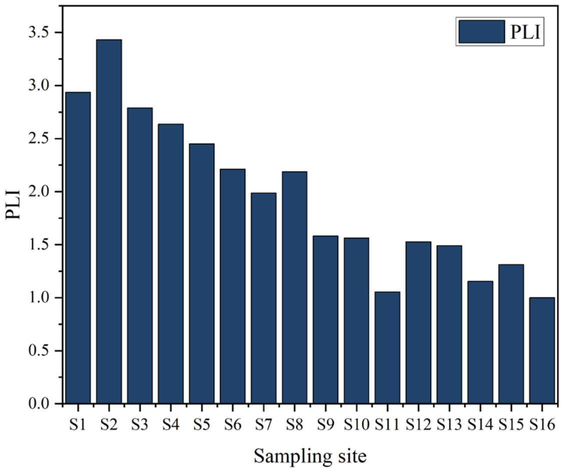

Fig. 8 Schematic diagram of microplastic pollution load index

The potential harm of microplastics to ecosystems depends not only on their abundance, but also on the toxicity that may arise from their different polymer compositions and the additives used in plastic production. As shown in Fig. 9, the polymer risk index in the surface water of the DaSha River was generally at medium to high risk levels, with sampling site S16 even reaching an extremely high-risk level. The polymer risk scores of microplastics in the water body were classified as low, medium, high, and extremely high, accounting for 6.25%, 37.5%, 50%, and 6.25%, respectively, with values ranging from 9.49 to 2641.33. Although the abundance of microplastics at site S4 was relatively high, the hazard scores of the polymer types present were low, resulting in a relatively low polymer risk index. In contrast, sites S15 and S16 had relatively low microplastic abundances but contained polymer types with high hazard scores, such as PVC and PAN, leading to higher polymer risk indices. This indicates that there is no significant correlation between the polymer chemical toxicity risk index and the overall microplastic abundance.

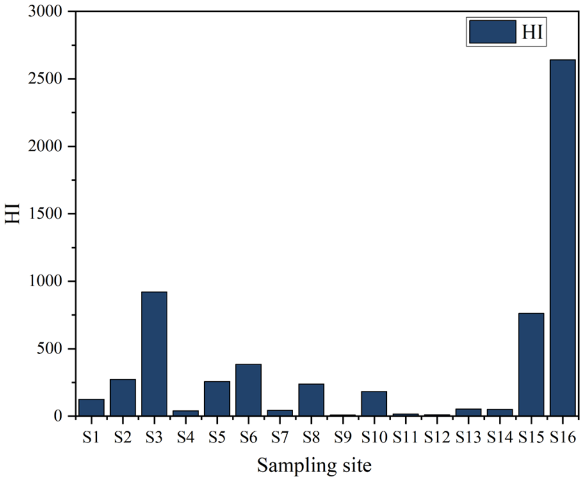

Fig. 9 Schematic diagram of microplastic polymer risk index

5. Conclusions

This study analyzed the distribution characteristics of microplastic pollution in the water body of the DaSha River in Jiaozuo City and conducted an ecological risk assessment. The results showed that the detection rate of microplastics in the DaSha River was 100%, with abundances ranging from 0.9 to 10.6 $n \cdot L^{-1}$ and an average abundance of 3.90 ± 2.83 $n \cdot L^{-1}$, which is relatively lower compared to other water bodies. Fibers were the predominant shape of microplastics, accounting for as high as 82.43%; most particles had sizes between 0.3 and 1.0 mm, with black and transparent being the main colors; the primary polymer types were PET, PA, and PP, which may be related to discharges from surrounding industries and residential activities. Using the Pollution Load Index and the Polymer Risk Index for microplastics, it was found that the overall pollution load index ranged from 1 to 3.43, with a risk level of I. However, sampling sites containing microplastics with high hazard scores, such as PVC and PAN, exhibited relatively higher polymer risk indices, potentially posing certain risks to the local ecological environment. Targeted control measures should be implemented for these specific areas to mitigate potential ecological risks.

Conflicts of interest

The authors declare that they have no conflict of interest.

References

[1] WANG H, JIANG G. Identification, Toxicology and Health Effects of New Pollutants[J]. Chemical research in Chinese universities, 2023,39(3): 325.

[2] KHAN S, NAUSHAD M, GOVARTHANAN M, et al. Emerging contaminants of high concern for the environment: Current trends and future research[J]. Environ Res, 2022,207: 112609.

[3] COCCIA M, BONTEMPI E. New trajectories of technologies for the removal of pollutants and emerging contaminants in the environment[J]. Environ Res, 2023,229: 115938.

[4] SHEHU Z, NYAKAIRU G W A, TEBANDEKE E, et al. Overview of African water resources contamination by contaminants of emerging concern[J]. Sci Total Environ, 2022,852: 158303.

[5] SAJAD S, ALLAM B K, DEBNATH A, et al. Pollution status of microplastics in the sediments of warm monomictic Dal lake, India: Abundance, composition, and risk assessment[J]. Environ Pollut, 2024,363(Pt 2): 125247.

[6] AMBROSINI R, AZZONI R S, PITTINO F, et al. First evidence of microplastic contamination in the supraglacial debris of an alpine glacier[J]. Environmental pollution (1987), 2019,253: 297-301.

[7] DEVEREUX R, AYATI B, WESTHEAD E K, et al. "The great source" microplastic abundance and characteristics along the river Thames[J]. Marine pollution bulletin, 2023,191: 114965.

[8] ANAND U, DEY S, BONTEMPI E, et al. Biotechnological methods to remove microplastics: a review[J]. Environ Chem Lett, 2023,21(3): 1787-1810.

[9] KABIR A H M E, MASAHIKO S T I K. Science of the Total Environment[J]. Science of the Total Environment, 2022.

[10] LI J, OUYANG Z, LIU P, et al. Distribution and characteristics of microplastics in the basin of Chishui River in Renhuai, China[J]. Sci Total Environ, 2021,773: 145591.

[11] CHEN H L, GIBBINS C N, SELVAM S B, et al. Spatio-temporal variation of microplastic along a rural to urban transition in a tropical river[J]. Environmental pollution (1987), 2021,289: 117895.

[12] XU N, JIANG L, ZHANG Y, et al. Microplastic pollution in the offshore sea, rivers and wastewater treatment plants in Jiangsu coastal area in China[J]. Mar Environ Res, 2023,188: 105992.

[13] QIU Y, ZHOU S, ZHANG C, et al. A framework for systematic microplastic ecological risk assessment at a national scale[J]. Environmental pollution (1987), 2023,327: 121631.

[14] HAQUE M R, ALI M M, AHMED W, et al. Assessment of microplastics pollution in aquatic species (fish, crab, and snail), water, and sediment from the Buriganga River, Bangladesh:An ecological risk appraisals[Z]. Amsterdam: Elsevier Pub.Co, 1972.

[15] PAN Z, LIU Q, JIANG R, et al. Microplastic pollution and ecological risk assessment in an estuarine environment: The Dongshan Bay of China[J]. Chemosphere (Oxford), 2021,262: 127876.

[16] LITHNER D, LARSSON A, DAVE G. Environmental and health hazard ranking and assessment of plastic polymers based on chemical composition[J]. Sci Total Environ, 2011,409(18): 3309-3324.

[17] HUANG Q E, ZE L, MENGGE L, et al. Occurrence of microplastics pollution in the Yangtze River: Distinct characteristics of spatial distribution and basin-wide ecologicalrisk assessment[J]. Water Research, 2022(229 (2023)): 119431.

[18] DING L, MAO R F, GUO X, et al. Microplastics in surface waters and sediments of the Wei River, in the northwest of China[J]. Sci Total Environ, 2019,667: 427-434.

[19] YAN M, NIE H, XU K, et al. Microplastic abundance, distribution and composition in the Pearl River along Guangzhou city and Pearl River estuary, China[J]. Chemosphere, 2019,217: 879-886.

[20] JI X, YAN S, HE Y, et al. Distribution Characteristics of Microplastics in Surface Seawater off the Yangtze River Estuary Section and Analysis of Ecological Risk Assessment[J]. Toxics, 2023,11(11).

[21] GONZÁLEZ-PLEITER M, VELÁZQUEZ D, EDO C, et al. Fibers spreading worldwide: Microplastics and other anthropogenic litter in an Arctic freshwater lake[J]. The Science of the total environment, 2020,722: 137904.

[22] ZAINUDDIN A H, ARIS A Z, ZAKI M R M, et al. Occurrence, potential sources and ecological risk estimation of microplastic towards coastal and estuarine zones in Malaysia[J]. Marine pollution bulletin, 2022,174: 113282.