Microplastics Monitoring in Environmental Matrices of an Alpine River originating from Hindu Kush Mountain Range

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Abstract

Microplastics (MPs) are cosmopolitan in distribution and an emerging threat to life and the environment. These particles are not restricted to human-inhabited lands but also found in different mountains and glaciers where the human population is relatively low. These MPs make their way to the river ecosystem from glaciers, rains, and municipal and industrial effluents. The current study was designed to highlight MPs' pollution in water, sediments, and fishes of the Swat River: originating from the Hindu Kush Mountain Range. These samples were collected from eight different sites across the river. The average MPs concentrations were 305.79 ± 289.66 MPs/m³, 588.29 ± 253.95 MPs/kg, and 12.54 ± 8.02 MPs/individual the water, sediments, and fish samples, respectively. The highest MPs concentrations (753.71 ± 330.08 MPs/m³) in water were recorded near Mingora City, whereas MPs concentrations (834.0 ± 367.21 MPs/kg) were the highest on the same site. Among the selected fish species, the highest number of MPs was observed in *Shizothorax plagiostomus*. In contrast, the lowest in *Wallago attu* being 17.08 ± 8.27 . Among the selected fish species, the highest number of MPs was observed in *Shizothorax plagiostomus*, whereas the lowest in *Wallago attu* being 17.08 ± 8.27 MPs/individual and 5.0 ± 2.36 MPs/individual, respectively. Fibres were the most prevalent MPs in all the matrices representing 80%, 92%, and 85% of the total MPs count in water, sediments, and fish samples. These findings highlighted that the high concentration of MPs prevailing in the river originating from high-altitude freshwater sources and awareness, education, ecotourism, sustainable reduction in plastic use, and strict rules and regulations could be helpful to prevent the anthropogenic menace.

1. Introduction

It has been estimated that about 368 million tons of plastics are used per year worldwide, and this amount is increasing daily at an alarming rate (Plastics Europe 2020). Most plastic products are disposable and thrown away after their single-use (Barnes et al. 2009; Hopewell et al. 2009). Extensive usage, limited recycling, and durability of plastic polymers are the most critical factors for plastic waste accumulation in the environment (Thompson. et al. 2009). The problem of plastic pollution aggravates when the macroplastic items disintegrate into smaller particles due to different physical, chemical, and environmental factors (GESAMP 2015). The large-sized plastics (> 5mm) are Macroplastics, while the small-sized plastic particles termed micro (1-5mm), meso (0.1µm-1mm), and nano-plastics (< 0.1µm) based on their size ranges. The MPs can also be terms as primary or secondary, where the term primary refers to particles produced in the micro size and secondary refers to MPs produced by the breakdown of MPs (Hanslik, 2020; Napper et al. 2015).

The toxic effects of MPs cannot neglected because these MPs carry different types of organic pollutants. Several studies support their ingestion and retention in other parts of the gastrointestinal tract in the aquatic, terrestrial, and avian fauna (Jabeen et al., 2017; Zhang et al., 2017). This ingestion and retention can be associated with many physical, physiological, neural, and hormonal problems, mainly reducing the nutrient-absorption area of the intestine, inhibition of gastric and pancreatic enzymatic activity, decreased steroid hormones, and late ovulation (Canesi et al. 2015). Numerous studies have been

reported across the globe concerning freshwater MPs, of which many studies are only focused on MPs presence in water and sediment samples with no or less focus on the aquatic biota (Schmid et al. 2020; Scherer et al.2020; Tunali et al.2020; O'Connor et al.2019; Li et al.2018; Peng et al. 2018; Rochman et al.2017). Previously, the focus of the research was towards the marine organisms, but recently, a few studies have also been reported on freshwater fishes, but none of them is from Pakistan; however, several studies have been documented from different regions all over the world (Kasamesiri et al.2020; Kuśmierk and Popiolek, 2020; Sun et al. 2020; Wang et al. 2020; Zhang et al.2020a).

Recently, Jian et al.(2020) have reported MPs in water and sediments from China's most extensive freshwater lake system. Wang et al.(2020) highlighted MPs in Beijing River and Pearl River China, while Zhang et al. (2020b) published a study on the Yongjiang River. Many other reports have also been published in the last two years, including Li et al.(2020), Cera et al.(2020), Erdoğan (2020), Guan et al. (2020), Wu et al.(2020), Yang et al.(2020), Neama et al.(2020), Akindele et al. (2019), Bordos et al. (2019), Yaun et al. (2019). However, Pakistan lags far behind, and published literature regarding freshwater MPs pollution consists of only two studies conducted on Rawal Lake and Ravi River (Irfan *et al.*2020a; Irfan et al.2020b). However, there is no such research on freshwater fish from Pakistan, so the current study is the first to establish a correlation between MPs in freshwater fish, sediments, and surface water in the country. Moreover, the Swat River is the remote river at a high altitude in the Northern mountains of Pakistan. Only a few studies have been reported globally to assess the MPs pollution in remote regions. This study can be a valuable addition to present MPs literature to establish a relationship between MPs pollution level and ingestion in different fish species. It can also be significant to indicate potential sources of plastic pollution in such remotely located freshwater bodies.

2. Material And Methods

2.1. Study area

The Swat River is a 240 km long river located in Khyber-Pakhtunkhwa (KPK), Pakistan. This perennial river has a basin area of 14,000 km² and receives plastic waste mainly due to fishing and tourism activities in the catchment area before joining Kabul River, near Sardaryab (Charsadda-KPK). A total of eight sampling sites ($n = 8$) were selected for the water, sediments, and fish sampling, including six sites located along with River Swat ($n = 6$; Kalam, Bahrain, Madyan, Mingora, Chakdara, Charsadda) and two locations ($n = 2$) along with the Confluence point of River Swat and Kabul (Figure. 1).

2.2. Sampling protocols

A total of 24 samples ($n = 24$) were collected from eight sampling sites, and triplicate samples were performed for the surface water and sediments and Passive surface water from each site. The MPs in water were collected from each site using a manta trawl with a mesh size of 300 μm (Vermaire et al. 2017). The stationary manta trawl net was deployed thrice and fixed at a position along the river's width (left-side, midstream, right-side) for one hour. The trapped anthropogenic material was separated from the collecting pock of Manta trawl, further rinsed with distilled water into a 500 ml amber glass jar to get

maximum material. Three sub-samples of Sediment samples collected from 1 cm depth from the shoreline of the same area, from where MPs collected the surface water following the pre-defined methodology. The shoreline sediments sampled using a stainless-steel quadrat (30 cm) and a spatula, the collected sample stored in a Glass Jar (Irfan et al. 2020a; Klein et al. 2015). A total of 24 fish samples ($n = 24$) belonging to 4 different species were collected using rods and Nylon hand fishing nets with the help of local fishermen. The collected samples were weighed, labelled, and stored in the icebox and transported to the Environmental Toxicology laboratory, College of Earth and Environmental Sciences, University of the Punjab, Lahore, Pakistan. The fish samples were stored in a refrigerator while water and sediment samples stored kept at room temperature before further analysis.

2.3. Preparatory steps

The water samples digested using hydrogen peroxide along with Fenton reagent. After digestion of organic matter, MPs were segregated using density separation techniques. A customized density separator was used to segregate MPs from the digested sample with concentrated NaCl solution (Irfan et al. 2020a; Coppock et al. 2017; Zobkov and Esiukova 2017). About 600 ml NaCl solution was applied and remained undisturbed for 6–8 hours of settling time. The supernatant layer was collected and filtered through 300, 150 and 50 μm sieves to get three different size fractions (Irfan et al. 2020a). Each prepared sieve back washed, and MP contents filtered onto filter papers using a vacuum filtration assembly.

The sediment samples were digested and separated, adopting methods (Cashman et al. 2020; Zobkov and Esiukova 2017). For wet peroxide digestion, About 50 ml of Fenton's solution was added to the sediment sample in a 500 ml glass beaker and filtered through a 50 μm sieve (Irfan et al. 2020a). Then, placed the beaker on a water bath for heating up at 75°C until the digestion of the organic content. The supernatant was then filtered through 300, 150, and 50 μm sieves and transferred to filter papers as described earlier.

Fish samples were thawed for 1–2 hours and dissected to collect their guts. Each gut sample of fish was weighed and digested in 250 ml glass bottles using 10% KOH solution with a 5:1 ratio with the sample. Then, incubate the sample at 55°C for 36 hours. Sodium Chloride (3:1 v/v) was added to the digested material immediately and thoroughly stirred for 20 minutes before being left to settle for 2 hours (Pellini et al. 2018). The supernatant layer was collected and filtered through 300, 150, and 50 μm sieves to get three different fractions. The solid contents of each fraction from sieves then backwashed and transferred to filter paper (MCE 0.45 μm pore size and 47 mm diameter) using a vacuum filtration assembly. The walls of the filtration assembly cup washed twice, and the filter papers containing solids dried up for one day in a Petri dish covered with Aluminum foil before detection.

2.4. Identification and classification of MPs

After drying, the solid material at filter papers analyzed under a stereomicroscope with a digital camera. Then examined coarse range of analyte on filter papers (prepared from 300 μm sieves) under the microscope. At the same time, observation for a fine range of MPs made on the filter papers (from 150 and 50 μm sieves) under the microscope with a digital camera (Irfan et al. 2020a). The physical shape

and colour of MPs were used for the identification of MPs. These MPs further classified into fibres, sheets, fragments, foams, and beads. Internationally recognized units viz; MPs/individual, MPs/m³, and MPs/kg for the fish, water, and sediment samples, respectively (Hidalgo-Ruz et al. 2012).

2.5. Statistics and computations

Descriptive statistics, ANOVA, and Pearson correlation were calculated by SPSS 18. The volume of water filtered through the manta trawl net was calculated using a modified flow rate formula as given below:

$$Vol = Avt$$

Where,

Vol = Volume of sampled water in m³

A = Area of manta trawl mouth in m² (*width × height*)

V = Average velocity of the river in m/s

t = Sampling time in seconds

2.6. Laboratory Contamination Control

All the precautionary measures considered to prevent material and laboratory contamination. A dedicated portion in the laboratory was used for MPs samples to avoid cross-contamination. The tools and glassware used during the sampling and analysis were carefully rinsed with distilled water and covered with aluminium foil when not being used. Reagents and distilled water were also filtered using and covered with aluminium foil to avoid atmospheric contamination. A few filter papers were placed on random locations in the lab for 72 hours to measure the suspended load of MPs from the laboratory environment then analyzed under the stereomicroscope. Six such filter papers were examined during the whole analysis and kept as a control. MPs on the filters were subtracted from the sample to avoid the atmospheric contamination from the laboratory environment.

3. Results And Discussion

3.1. MPs level in Swat River

An average concentration of MPs detected in water samples (305.79 ± 289.66 MPs/m³), fish (12.54 ± 8.02 MPs/individual), and sediments (588.29 ± 253.95 MPs/kg; Figure. 2). The highest concentration was observed among water samples at Mingora city and the lowest at the confluence point of the rivers near Charsadda being 753.71 ± 330.08 MPs/m³ and 57.64 ± 31.98 MPs/m³, respectively. MPs concentrations in the sediment samples were also the highest at Mingora city (834.0 ± 367.21 MPs/kg), but the lowest concentrations were recorded in sediments collected from Chakdara (215.0 ± 20.0 MPs/kg). Among the fish samples, *Shizothorax plagiostomus* contained the highest while *Wallago attu* contained the lowest

MPs concentrations corresponding to 17.08 ± 8.27 MPs/individual and 5.0 ± 2.36 MPs/individual, respectively (Figure. 3).

The present concentrations of MPs in high altitude surface water (2000 m at Kalam and 980 m at an average altitude of Swat River) were comparable with other high-altitude studies. In a recent study from China, Mao et al. (2020) reported 360 MPs/ m³ in one of the three gorges in Yulin River at an altitude of 1084 m. Feng et al. (2020) described 584.82 MPs/ m³ in freshwater lakes and rivers from Qinghai Tibet Plateau, China, located at 4000 m above sea level. The similarity in the average MPs concentrations at higher altitude are more likely due to tourism activities being the primary source of pollution in these areas, as commonly these areas are less populated (Comakli et al. 2020). The increasing number of tourists in these areas leaves behind many plastic food wrappers, disposables, plastic bags, and other types of waste plastics. At higher altitude, the large volume of plastic packed food and different kinds of plastic carried by the tourists. This process supported by a study from Mount Everest where Napper et al. (2020) reported 1000 MPs/m³ in one of the streams. Comparable results also have been reported from other regions of the world, such as 400 MPs/m³ from the Trent River, UK, and 400 MPs/m³ from an Australian freshwater ecosystem (Stanton et al. 2020; Nan et al. 2020). The present concentrations of MPs are lesser than the previous studies from Pakistan, where 2074 ± 3651 MPs/m³ reported from Ravi River, Lahore, and 1420 MPs/m³ (originally 0.142 items/0.1 L) from Rawal Lake, Rawalpindi (Irfan et al. 2020a; Irfan et al. 2020b). The higher concentrations of MPs in these reports are related to higher population density and those water bodies compared to Swat River. The MP concentrations from the Ravi River were also higher than Rawal Lake and swat river because Lahore is the second highly populated metropolitan city and an industrial hub of the country.

The MPs concentration in fish also found to be comparable with the findings of Pegado et al. (2018), who reported an average concentration of 12.8 MPs/individual and 7.8 MPs/individual in *Bagre bagre* and *Bagre marinus* from Amazon River, respectively. Pazos et al. (2017) reported a higher concentration than the present study with 19 MPs/individual from the Argentinean freshwater ecosystem. Recent studies from China have reported lower concentrations of 0.2 ± 0.5 MPs/individual from the Beijing River and 4.8 MPs/individual from the Pearl River (Wang et al. 2020; Roch et al. 2019). A similar pattern of MPs was highlighted by Sun et al. (2020) in river water. In contrast, Zhang *et al.* (2020) described the concentration of 4.25 MPs per individual and 0.6 MPs per individual from other Chinese regions. The variation in reported concentrations with the present study may be due to different species with different feeding habits. Carnivore species will get higher concentration as feeding on fishes with ingested MPs compared to herbivores fish species. Further, the habitat of fishes also affects the concentration of MPs consumed by fishes because the availability of MPs varies in different zones of an aquatic ecosystem.

Similarly, MPs concentrations in the sediment samples were also comparable to the concentrations reported from surrounding areas. There were 403 MPs/kg reported from Dongting Lake and 90–550 MPs/kg in Yongjiang River (Yin et al. 2019; Zhang et al. 2019). High concentrations reported from Elbe River, Germany, containing 3350 MPs/kg at an altitude of 1,386 m above sea level (Scherer et al. 2020).

The possible reason for this higher concentration in the Elbe River, which 25 Million inhabitants inhabit as compared to the Swat River inhabited by 2.31 million people. Hence have a direct impact on the pollution profile of the river. Due to high population density, higher concentrations reported from Poyang Lake, China, and the Northern-Tunisian freshwater stream with 1936 ± 121 MPs/kg and 2340 ± 227.15 MPs/kg, respectively (Jian et al. 2020; Toumi et al. 2020). Several studies reported the low concentrations of MPs in comparison to the current study; viz; Veeranam Lake, India (309 MPs/kg), Yongfeng River, China (26 ± 23 MPs/kg), Citarum River, Indonesia (166 MPs/kg), Shuangtaizi River, China (170 ± 96 MPs/kg) and Diliao River, China (237 ± 129 MPs/kg). These concentrations are lower than the present study due to multiple geographic and demographic factors (Srinivasalu et al. 2020; Sembiring et al. 2020; Xu et al. 2020). Furthermore, a comparison of some recent studies on concentrations of MPs given in Table 1.

Table 1
Comparison of MPs concentrations reported by different studies

Medium	Region	Concentration	Reference
Water	Pakistan	305.79 ± 289.66 MPs/m ³	Present Study
	China	360 MPs/m ³	Mao et al. (2020)
	China	584.82 MPs/m ³	Feng et al. (2020)
	UK	400 MPs/m ³	Stanton et al. (2020)
	Pakistan	1420 MPs/m ³	Irfan et al. (2020b)
	Pakistan	2074 ± 3651 MPs/m ³	Irfan et al. (2020a)
	Australia	400 MPs/m ³	Nan et al. (2020)
	Nepal	1000 MPs/m ³	Napper et al. (2020)
	China	1660 ± 639.1 to 8925 ± 1591 MPs/m ³	Wang <i>et al.</i> (2017)
	South Africa	258 ± 53-1215 ± 277 MPs/m ³	Nel and Froneman (2015)
Sediments	Pakistan	588.29 MPs/kg	Present Study
	Indonesia	166 MPs/kg	Sembiring et al. (2020)
	China	237 ± 129 MPs/kg	Xu et al. (2020)
		3350 MPs/kg	Scherer et al. (2020)
	China	1936 ± 121 MPs/kg	Jian et al. (2020)
	India	309 MPs/kg	Srinivasalu et al. (2020)
	Tunisia	2340 ± 227.15 MPs/kg	Toumi et al. (2019)
	China	26 ± 23 MPs/kg	Rao <i>et al.</i> (2019)
	Canada	610 MPs/kg	Ballent et al. (2016)
	Canada	616 MPs/kg	Corcoran <i>et al</i> (2015)
Fish	Pakistan	12.54 MPs/individual	Present Study
	China	4.8 MPs/individual	Wang et al. (2020)
	China	4.25 MPs/individual	Sun et al. (2020)
	China	0.6 MPs/individual	Zhang <i>et al.</i> (2020)
	China	0.2 ± 0.5 MPs/individual	Roch et al. (2019)

Medium	Region	Concentration	Reference
	Brazil	12.8 MPs/individual	Pegado et al. (2018)
	Argentina	19 MPs/individual	Pazos et al. (2017)

3.2. Shapes and Size Of MPs

Among the water samples, the relative proportion of the fibres remained the highest (80%), and the fragments were minimum (6%). Comparable relative dominance of fibres also observed by Jian et al. (2020), where fibres were dominant (25–50%) and the fragments were the least (< 25%) among all types of MPs. Scherer et al. (2020) reported 46.5% of fibres and 22.9% fragments, while Zhang et al. (2019) detected 73.90% of fibres and 13.8% fragments in their findings. Sutton et al. (2016) also reported the same pattern in the present study where fibres were 80%, and fragments were 17% of total MPs. Likewise, Baldwin et al. (2016) also reported fibres to be the highest (71%) among the detected MPs concentrations. In another study conducted by McCormick et al. (2014) fibres and fragments followed the same trend being 59.28% and 37.14%, respectively. Mason et al. (2016) reported fibres to be 59%, and fragments being 33% of their total MPs count. A recently published study from Pakistan also reported the dominance of fibres in Rawal Lake, with fragments being the second abundant (Irfan et al. 2020b). However, a different trend reported in the second study from Pakistan, where fragments were the most dominant (56.1 %) and fibres were the second abundant type (38.6%) among the total MPs detected (Irfan et al. 2020a). These variations result from the inflow of untreated municipal and industrial wastewater into the Ravi River that has deformed the natural shape of the river. The contribution of foams and sheets in the present study was 12% and 2%, respectively, while beads did not observe in any samples. Swat River is not highly polluted, so most of the fibres were broken pieces of fishnets, with some of them from households and clothing.

Fibres were found the most abundant MPs type within the sediment samples contributing about 92% to the observed MPs. A recent study by Yin et al. (2020) also reported fibres as a dominant type of MPs with 41–49 to 100 % of the total types of MPs. The same highest proportions of fibres documented by Sembiring et al. (2020). In another study, Zhang et al. (2019) detected the fibres in sediments to be 60%, with fragments being 30%. The order of different types of MPs abundance detected in present sediment samples was fibers (92%) > fragments (6%) > sheets (2%) > foams and beads (0%). Irfan et al. (2020b) also reported a similar trend in relative abundance, with fibres being dominant over fragments and beads. The low quantity of sheets identified from the sediment owing to flow just beneath the water surface. That's why sheets are generally not deposited into sediments because of the low density of sheets, large surface area, and fast streamflow. Similarly, the absence of beads indicates negligible manufacturing and usage of industrial and cosmetic products in the catchment area.

Following the similar trend as observed in water and sediments, fibers were also dominant in fishes (88%) followed by sheets (7%), fragments (5%), and foams (0%). In the present study, the sheets ranked as the second most ingested form of MPs because they keep floating below the water's surface for being lighter

in weight than fragments, which increases their chance of ingestion during fish feeding. Recently, Kuśmierk and Popiolek, (2020) described the similar trend of the highest proportion of fibres (99.8%) in the gastrointestinal tract of freshwater fish. Zhang et al. (2020 b) and Wang et al. (2020) also reported that the fibres with the highest concentration in native freshwater fish belonging to different trophic levels from Pearl River South China. The possible reason for the highest proportion of fibres in fish species may be its difficulty to excrete with faeces as fibres stick with intestinal walls firmly compared to other shape MPs. Further comparison among relative abundance of MPs shapes given in Table 2. Phytophagous species may ingest the fibres accidentally as these fibres may resemble algae and phytoplankton.

Table 2
Relative abundance of different MPs shapes reported by different studies

Medium	Fibers	Sheets	Fragments	Foam	Beads	Reference
Water	80%	2%	6%	12%	0%	Present study
	25–50%	-	< 25%	-	-	Jian et al. (2020)
	46.5%	-	22.9%	-	-	Scherer et al. (2020)
	73.9%	-	13.8%	-	-	Zhang et al. (2019)
	59%	5%	33%	2%	1%	Mason et al., (2016)
	80%	2%	17%	1%	0%	Sutton et al., (2016)
	71%	-	-	-	-	Baldwin et al., (2016),
	59.28%	0.07%	37.14%	1.25%	2.26%	McCormick et al., (2014)
Sediments	92%	2%	6%	0%	0%	Present study
	41–100%	-	-	-	-	Yin et al. (2020)
	60%	-	30%	-	-	Zhang et al. (2019)
	24.86%	52.3%	22.74%	0%	0.1%	Wahyuningsih et al., (2018)
	73%	2%	21%	4%	0%	Eshom-Arzadon, (2017)
	22.3%	12%	47.7%	18%	0%	Wessel <i>et al.</i> , (2016)
Fish	88%	7%	5%	0%	0%	Present study
	99.8%	-	-	-	-	Kuśmierk and Popiolek, (2020)

In terms of defined size, the large sized MPs (300µm) were dominant in water samples (62%) followed by medium-size MPs (150 µm; 20%) and small size MPs (50 µm; 18%). This trend was comparable to the findings from Ravi River, Lahore-Pakistan, where larger MPs particles were dominant (Irfan et al.2020a). Zhang et al. (2019) also reported MPs in size range 330µm-1mm to be in the highest proportion (59.1%) compared to other size classes. The highest proportion of larger sizes MPs may be due to continuous

activities by local inhabitants and tourists, such as using nets for fishing and the breakdown of plastic disposable being left at the bank of the river or directly thrown into the river. In fish samples, the overall relative abundance of MPs followed a similar trend as in the surface water, and prominent size MPs were dominant (43%), followed by small size MPs (29%) and medium-sized MPs (28%). MPs with sizes up to 1000 μm reported being highest (70.5%) in a study by Sun et al. (2020), whereas Wang et al. (2020) reported that 80% of the detected MPs belonged to the size range of 500–1000 μm . The relative proportion of ingested MPs sizes also varied according to the fish feeding habit. Large-sized MPs contributed 76% in carnivorous, 75% in filter-feeding, 59% in omnivorous, and 53% in herbivorous fish. Furthermore, the dominance of larger MPs particles and the lower proportion of smaller sizes particles in the gut contents may be due to fish inability to excrete along with faeces.

Larger size MPs (300 μm) were also dominant in the sediment samples (44%), followed by medium and small-sized MPs in an equal proportion. A similar trend in MPs ratio reported from Veeranam Lake India, with large sized MPs being the most abundant (Srinivasalu et al. 2020) Zhang et al. (2019) reported the highest concentration (44.8%) of MPs with the size range of 330–1000 μm as compared to other sizes. Rao et al. (2019) also found larger MPs particles (200–1000 μm) to be the dominating (40.68%). The reason behind the highest proportion of large-sized MPs in sediments might be their high density causing them to offloaded on sediments as compared to smaller particles (Fig. 4). Another deciding factor may be the velocity of the water. In the case of Ravi River, the medium-size MPs (150–300 μm) reported being with the highest proportion in the sediment samples (Irfan et al. 2020a). The higher velocity of the Swat River slows down the bottom settling of large-sized MPs, while in the case of the Ravi River, it is higher due to lower speed.

4. Conclusion

The present research findings showed that the contributions of large-sized MPs (300 μm) were the highest in all the surface water, sediments, and fish samples from a higher altitude to the plain reaches of Swat River, Pakistan. Based on MP types, the fibres were in high proportions in the overall samples. The present study indicated that Swat River is suffering from indiscriminate use of plastic in the catchment. Due to the high influx of tourists, MPs pollution has been increased, resulting in a large volume of plastic waste directly or indirectly disposed into the river. It is highly recommended to start an organized campaign to educate the local community and tourists to minimize plastic and stringent enforcement of plastic reduction laws to manage this problem and make it an eco-friendly tourist destination.

5. Declarations

Compliance with ethical standards

Conflict of Interest: The authors declare that they have no conflict of interest.

Ethical approval: Not Applicable

Consent to participate: All persons involved in this research paper are well connected with me and I am available to all these people if anyone seeks further clarification and information.

Consent to publish: The contributing authors grant the sole and exclusive copyright of this manuscript to the journal/ publisher. The journal/ publisher will have them all right throughout the world to publish, distribute and sell the manuscript in any languages, either in printed or electronic form.

Author's Contributions:

Muhammad Bilal involved in sample collection and analysis, writing-original draft- and editing-supporting.

Abdul Qadir conceptualized, supervised, arranged the funding, administrated the project, reviewed, and edited the manuscript; Atif Yaqub: Supervised, and reviewed the research work. Muhammad Irfan participated in Method Validation, data analysis and review and editing. Mehmood Aslam participated in chemical analysis and statistical analysis; Rehan Ullah provided field support in sample collection, transportation and writeup.

Availability of data and materials: The supplementary file/datasets during the present study are available in the attached file.

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Figures

Figure 1

Map of Swat River indicating sampling sites Note: The designations employed and the presentation of the material on this map do not imply the expression of any opinion whatsoever on the part of Research Square concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries. This map has been provided by the authors.

Figure 2

Comparison of MPs concentration in water, sediments and fish samples collected from Swat River

Figure 3

Ingested MPs concentrations among different fish species depending on their trophic level

Figure 4

Relative abundance of MPs among the selected matrices based on shape and size wise

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