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Characterization of Microplastics by Size, Shape, and Color in Freshwater Sources of Punjab

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Abstract:

Microplastic contamination has become an important environmental concern because these persistent particles can accumulate in freshwater ecosystems and enter aquatic food webs. This study characterized suspected microplastics according to their size, shape, and colour in selected freshwater sources of Tehsil Pattoki, Punjab, Pakistan. The investigation was based on data generated during the author's undergraduate thesis. Twelve one-litre water samples were collected from different sources, including running canal water, standing surface water, swamp water, groundwater, tap water, filtration plants, a swimming pool, a pond, and null water. Samples were processed through stacked sieves of ≥2.0 mm, ≥0.5 mm, ≥0.35 mm, and 0.5 µm. The retained material was dried, treated with 5M sodium chloride solution, density-separated, filtered, and examined under a stereomicroscope at 40× magnification. Suspected particles were characterized according to visible size, shape, and colour. Microfibres, microbeads, and microfragments were the major morphological forms identified. Microplastics were detected in four of the twelve samples at concentrations of 6, 10, 12, and 15 particles per litre. The remaining eight samples contained no visually detected particles. Overall, 43 particles were recorded, producing a mean concentration of 3.583 particles per litre and a standard deviation of 5.407. The highest concentration occurred in standing swamp water. The thesis confirmed variation in particle size and colour but did not provide separate numerical frequencies for these categories. The findings provide baseline evidence of microplastic contamination in selected freshwater sources of Punjab and highlight the need for larger-scale monitoring and spectroscopic polymer identification.

Keywords: *microplastics, freshwater pollution, particle size, particle shape, particle colour, microfibres, microbeads, Punjab*

Introduction

Plastic materials are extensively used because they are lightweight, inexpensive, flexible, durable, and suitable for numerous commercial and domestic applications. Plastic products are commonly employed in packaging, clothing, construction, transport, agriculture, cosmetics, footwear, electronics, medicines, cleaning materials, and household products. Their resistance to degradation has contributed to their economic value, but it has also caused the accumulation of plastic waste in aquatic and terrestrial ecosystems. When plastic waste is released into the environment, it may remain present for long periods. Larger plastic items gradually become brittle and fragment under

the influence of ultraviolet radiation, temperature changes, mechanical abrasion, water movement, oxidation, and biological activity. These processes can produce small particles known as microplastics. Microplastics are generally defined as plastic particles measuring less than 5 mm. They may occur as fibres, beads, fragments, films, pellets, or foams. Their environmental behaviour depends on particle size, shape, density, chemical composition, surface condition, and interaction with sediments and organic materials (Castro et al., 2018; Zhang et al., 2021). Microplastics can be divided into primary and secondary categories. Primary microplastics are intentionally manufactured at a microscopic size. They may be used in cosmetics, face washes, medicines, industrial abrasives, scrubbers, and plastic-production processes. Secondary microplastics develop through the gradual fragmentation of larger plastic items, including bags, bottles, packaging, synthetic textiles, ropes, fishing materials, and agricultural sheets (Efimova et al., 2018). Freshwater ecosystems receive plastic contamination through domestic wastewater, agricultural runoff, industrial discharge, atmospheric deposition, urban drainage, and direct littering. Rivers and canals can transport microplastics over long distances, while ponds, wetlands, reservoirs, and standing water bodies may serve as accumulation areas. The physical characteristics of microplastics influence their movement and ecological effects. Smaller particles are more easily transported and may be ingested by plankton and other small organisms. Fibres may remain suspended in water, while relatively dense particles can settle in sediment. Colour may provide preliminary information about possible particle sources, although weathering and staining can alter the original colour. Microplastic research in Pakistan remains comparatively limited, particularly in inland freshwater environments. Tehsil Pattoki includes villages, agricultural areas, urban settlements, irrigation canals, filtration facilities, groundwater sources, ponds, and standing water bodies. These environments may receive microplastics from household waste, synthetic textiles, packaging, agricultural plastics, and untreated drainage. The present study characterized suspected microplastics by size, shape, and colour in twelve freshwater samples collected from Tehsil Pattoki, Punjab. It also assessed their concentration, distribution, and possible environmental sources.

Sampling and Laboratory Analysis:

Twelve water samples were collected from selected locations in Tehsil Pattoki on 12 June 2022. The sites represented running water, standing water, agricultural-area water, groundwater, tap water, filtration plants, a swimming pool, a pond, canal water, null water, and swamp water. Each sample was collected in a separate glass bottle and labelled from S-1 to S-12. The use of glass bottles helped reduce the possibility of contamination from plastic sampling containers. Information concerning the collection time, sampling location, latitude, longitude, altitude, water source, and geographical setting was recorded. Each water sample was passed through stacked sieves arranged according to particle-size thresholds of ≥2.0 mm, ≥0.5 mm, ≥0.35 mm, and 0.5 µm. The purpose of this procedure was to separate suspended materials according to their size. The solid materials retained by the sieves were transferred to filter paper and dried in the open air. After drying, the recovered material was mixed with 30 ml of 5M sodium chloride solution and stirred continuously for approximately three minutes. The mixture was poured into a density-separation apparatus and left overnight. Relatively heavy mineral and sediment particles settled at the bottom, whereas lightweight materials, including suspected plastic particles, remained in the upper layer. The upper layer was collected, filtered, and dried. The recovered particles were subsequently examined under a stereomicroscope at 40× magnification. Suspected microplastics were characterized according to their visible size, colour, shape, and physical appearance. The concentration of suspected particles was expressed as particles per litre. Mean, standard deviation,

correlation, and one-way analysis of variance were calculated from the recorded data. The samples were also classified according to rural and urban distribution. The analytical procedure was suitable for a preliminary microplastic assessment. However, visual microscopy cannot conclusively determine the polymer composition of every suspected particle. Natural fibres, paint particles, and other materials may resemble plastic under a microscope. Accordingly, the recorded materials should be described as suspected microplastics unless confirmed by FTIR or Raman spectroscopy.

Characterization According to Particle Size:

Particle size is an important factor controlling the environmental transportation, persistence, and biological availability of microplastics. The study classified particles smaller than 5 mm as microplastics. The stacked sieves separated the sampled material into fractions based on openings of ≥2.0 mm, ≥0.5 mm, ≥0.35 mm, and 0.5 µm. The use of multiple sieve sizes enabled relatively large particles to be separated from smaller materials. Particles retained by the ≥2.0 mm sieve represented the larger fraction of microplastics, whereas the finer sieves retained progressively smaller particles. Smaller particles can remain suspended in water for longer periods and may be transported over greater distances. In comparison, larger or denser particles may settle in sediments or accumulate around vegetation and other physical barriers. The interaction between size and density therefore affects the spatial distribution of microplastics. Particle size also influences biological exposure. Zooplankton, filter-feeding organisms, aquatic insects, molluscs, and juvenile fish may ingest small plastic particles. Lehtiniemi et al. (2018) concluded that size could be more influential than shape in determining the ingestion of primary and secondary microplastics by small aquatic predators. The thesis reported the presence of particles with different sizes. However, it did not present separate numerical counts or percentages for the individual sieve fractions. Consequently, it is not possible to calculate the proportion of particles within the ≥2.0 mm, ≥0.5 mm, ≥0.35 mm, and 0.5 µm categories. Ding et al. (2019) reported that particles smaller than 0.5 mm represented approximately 68.1% of microplastics detected in the Wei River in China. That study demonstrates the potential importance of small particles in freshwater ecosystems. Nevertheless, the percentage reported for the Wei River cannot be applied directly to the Pattoki samples. The smallest particles may have been underestimated because they are difficult to identify through stereomicroscopy. Future research should employ finer filtration, microscopic imaging, and spectroscopic analysis to determine size distributions more accurately.

Characterization According to Shape and Colour:

Three principal morphological forms of suspected microplastics were identified in the examined samples: microfibres, microbeads, and microfragments. The occurrence of different shapes indicates that contamination may have originated from multiple sources.

Microfibres appeared as thin and elongated particles. Synthetic textile materials such as polyester, nylon, and acrylic can release microscopic fibres during washing, drying, normal use, and environmental degradation. Laundry wastewater, discarded clothing, ropes, carpets, fishing materials, and industrial fabrics may therefore contribute microfibres to freshwater environments.

Microbeads are small spherical or rounded particles. They may originate from cosmetics, face washes, medicines, cleaning products, industrial abrasives, or untreated plastic-production materials. Because these particles are manufactured at a microscopic size, they are categorized as primary microplastics.

Microfragments are irregularly shaped particles produced through the breakdown of larger plastic objects. Plastic bags, bottles, containers, packaging, agricultural sheets, fertilizer bags, pesticide containers, construction materials, and household products can gradually fragment after environmental exposure. The presence of microfibres, microbeads, and microfragments suggests that the selected water bodies received both primary and secondary microplastics. Microbeads may have entered through wastewater and drainage, while fibres and fragments could have originated from textiles and degraded plastic waste. Shape influences particle behaviour. Fibres may remain suspended because of their elongated structure, while fragments may settle or become trapped in sediment depending on their density. Irregular fragments may also interact differently with aquatic organisms compared with smooth, rounded beads. The thesis reported that particles varied in colour. Particle colour may offer preliminary evidence about possible sources. Coloured fibres may be associated with synthetic clothing and fabrics. Brightly coloured fragments may originate from packaging, household products, toys, or agricultural materials. White or transparent particles may be linked to plastic bags, bottles, films, or packaging. However, colour cannot be used to confirm polymer composition. Ultraviolet radiation, oxidation, sediment staining, chemical exposure, and biofilm formation can alter the original appearance of plastic particles. Colour classification is also influenced by lighting, magnification, and observer judgement. The thesis did not provide individual counts for each colour or morphological category. Therefore, it would be scientifically inappropriate to calculate numerical percentages for fibres, beads, fragments, or colours. These characteristics can only be reported qualitatively from the available evidence.

Distribution and Concentration in Freshwater Sources:

Microplastics were detected in four of the twelve water samples. Samples S-3, S-6, S-9, and S-10 contained 6, 10, 12, and 15 suspected particles per litre, respectively. No particles were visually identified in samples S-1, S-2, S-4, S-5, S-7, S-8, S-11, and S-12.

Sample-Wise Results

Sample	Microplastics per litre
S-1	0
S-2	0
S-3	6
S-4	0
S-5	0
S-6	10
S-7	0
S-8	0
S-9	12

Sample	Microplastics per litre
S-10	15
S-11	0
S-12	0
Total	**43**
Mean	**3.583 particles/L**
Standard deviation	**5.407**

Sample S-10, representing standing swamp water, contained the highest concentration at 15 particles per litre. Sample S-9, obtained from standing surface water at UVAS, contained 12 particles per litre. Running canal-water sample S-6 contained 10 particles per litre, while sample S-3 contained 6 particles per litre. The higher concentration recorded in standing swamp water may have resulted from limited water circulation. Plastic particles entering a standing water body can remain trapped among vegetation, sediment, organic material, and floating waste. The occurrence of particles in running canal water may be associated with agricultural runoff, household wastewater, discarded plastic materials, or particles transported from upstream locations. Irrigation canals can distribute microplastics across rural and agricultural areas. No suspected particles were recorded in several tap-water, groundwater, filtration-plant, and null-water samples. These findings may indicate lower contamination or the removal of larger particles through filtration. However, zero recorded particles do not prove that the samples were completely free from microplastics because very small particles may not have been captured or identified. Based on the rural and urban classifications provided in the thesis tables, the rural group contained a total of 31 particles and had a mean concentration of 5.16 particles per litre. The urban group contained 12 particles and had a mean of 2.00 particles per litre. The one-way analysis of variance produced an F-value of 0.93 and a p-value of 0.35. Because the p-value was greater than 0.05, the difference between the rural and urban groups was not statistically significant. A correlation coefficient of −0.399 was also reported.

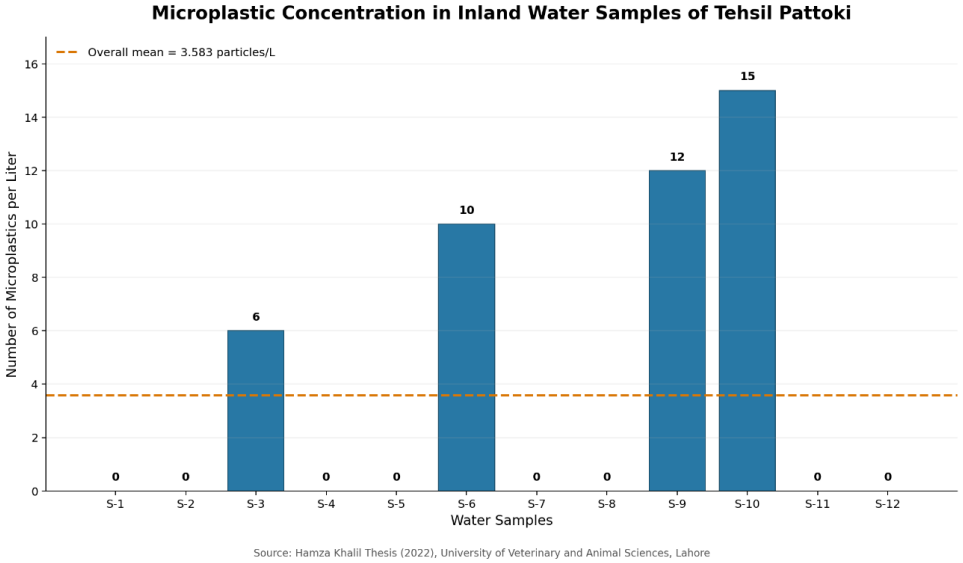
Environmental Effects and Potential Sources:

Microplastic contamination is environmentally important because particles may be consumed by organisms occupying different trophic levels. Zooplankton, insects, molluscs, crustaceans, fish, birds, and mammals may ingest microplastics directly or through contaminated prey. The biological effects of microplastics depend on particle size, shape, polymer type, concentration, and exposure duration. Small particles may be consumed more easily, while fibres and irregular fragments can interfere with feeding and digestion. Reported effects include intestinal blockage, false satiation, reduced food intake, inflammation, oxidative stress, altered growth, reproductive disturbance, and changes in metabolic functions. Hamed et al. (2019) observed changes in the blood biomarkers of juvenile Nile tilapia exposed to microplastics. Microplastics may also contain additives such as dyes, stabilizers, plasticizers, and flame retardants. Their surfaces can adsorb pollutants from surrounding water. Aquatic organisms may therefore be exposed to both the physical presence of particles and their associated chemicals. Potential sources in Pattoki include

domestic waste, packaging materials, plastic bottles, bags, agricultural sheets, fertilizer packaging, pesticide containers, irrigation equipment, synthetic clothing, laundry wastewater, cosmetics, and plastic litter deposited near water bodies. The occurrence of microfibres suggests possible inputs from textiles and domestic wastewater. Microbeads may be associated with personal-care products or industrial materials, while fragments probably resulted from the environmental degradation of larger plastic products. The present study did not directly examine microplastic ingestion by aquatic animals or determine human exposure. Its findings should not be used to establish specific health effects. Instead, the study provides baseline evidence showing that suspected microplastics are present in selected freshwater environments.

Management Measures and Future Research:

Plastic contamination should be controlled at its source. Municipal authorities should improve household waste collection, prevent open dumping, and regularly remove litter from canals, ponds, drainage channels, and standing water bodies. Agricultural plastic waste requires dedicated management. Fertilizer bags, pesticide containers, plastic mulch, greenhouse coverings, and damaged irrigation pipes should be collected and recycled or safely disposed of. Farmers should be informed about the long-term environmental consequences of leaving plastic materials in fields. Wastewater-treatment systems should incorporate filters capable of capturing synthetic fibres and small plastic particles. Households can reduce pollution by limiting unnecessary single-use plastics and avoiding the disposal of plastic waste in drains and open water channels. Future studies should collect samples from a larger number of freshwater sites across Punjab. Every location should be sampled repeatedly during dry and wet seasons. Seasonal data would help determine how rainfall, flooding, irrigation, and changing water flows influence particle concentrations. Freshwater analysis should be combined with sediment sampling because some microplastics settle at the bottom of water bodies. Fish, plankton, aquatic plants, and invertebrates should also be examined to investigate biological exposure. Particle size should be measured with appropriate imaging software, and separate numerical frequencies should be reported for every size, shape, and colour category. Such data would allow researchers to calculate percentages and compare particle characteristics across water sources. FTIR or Raman spectroscopy should be used to confirm polymer composition. Field blanks, laboratory blanks, filtered reagents, covered glassware, and non-synthetic laboratory clothing should be included to minimize contamination.



Summary

This study characterized suspected microplastics according to size, shape, and colour in twelve freshwater samples collected from Tehsil Pattoki, Punjab. Samples represented canals, standing surface waters, swamp water, groundwater, tap water, filtration plants, a pond, a swimming pool, and other inland water sources. Water samples were passed through stacked sieves with openings of ≥2.0 mm, ≥0.5 mm, ≥0.35 mm, and 0.5 µm. Retained materials were dried, mixed with 5M sodium chloride solution, density-separated, filtered, and examined under a stereomicroscope at 40× magnification. The principal morphological forms were microfibres, microbeads, and microfragments. Variations in particle size and colour were observed, but the thesis did not provide separate numerical frequencies for these characteristics. Suspected microplastics were found in four samples at concentrations of 6, 10, 12, and 15 particles per litre. A total of 43 particles was identified. The overall mean was 3.583 particles per litre, and the standard deviation was 5.407. Standing swamp water contained the highest concentration. The study provides preliminary evidence of microplastic contamination in selected freshwater sources of Punjab. Expanded sampling, detailed morphological measurements, quality controls, sediment analysis, and spectroscopic polymer confirmation are recommended.

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