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Integrated analysis of microplastics and heavy metals in the urban aquatic environment

Muhammad Ali[1]*, Adnan Noor Shah[2], Muhammad Nawaz[2], Salman Ahmad[3], Jameel M. Al-Khayri[4]*, Abdullateef M. Al Saeed[5], Abbas E. Rahma[5], El-Sayed A. Badr[5], Mustafa I. Almaghasla[6] and Hajiyev Sahib Asgar[7]

[1]Institute of Agro-Industry & Environment, The Islamia University of Bahawalpur, Pakistan
[2]Department of Agricultural Engineering, Khwaja Fareed University of Engineering and Information Technology, Rahim Yar Khan, Pakistan
[3]Department of Agronomy, Faculty of Agriculture & Environment, The Islamia University of Bahawalpur, Pakistan
[4]Department of Agricultural Biotechnology, College of Agriculture and Food Sciences, King Faisal University, Saudi Arabia
[5]Department of Environment and Agricultural Natural Resources, College of Agriculture and Food Sciences, King Faisal University, Saudi Arabia
[6]Plant Pests and Diseases Unit, College of Agriculture and Food Sciences, King Faisal University, Saudi Arabia
[7]Department of Geography, Nakhchivan State University, Azerbaijan
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*to whom all correspondence should be addressed: e-mail: aliiub61@gmail.com, jkhayri@kfu.edu.sa
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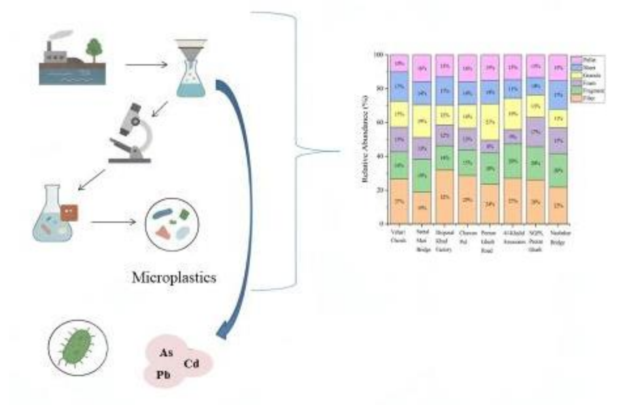
Graphical abstract



Abstract

Microplastics (MPs) are ubiquitous primarily in aquatic environment where they travel freely from one place to another. Higher surface area with strong hydrophobicity made them a perfect candidate to sorb different pollutants in aquatic ecosystem. This study investigates occurrence and distribution of MPs in Qasimpur canal running in Multan city and carries large quantity of sewage waste and industrial effluents. Twenty-five surface water samples were taken and examined regarding the abundance of microplastic, morphology, color distribution, and related heavy metals (As, Cd, Pb) and microbial contamination (total coliform and E. coli). Findings exhibit that MPs concentration is between 25 and 6 MPs L^{-1}. Relative distribution of MPs shows that fibers (32.01%) were prevalent in water sample followed by fragment (20.39%) while sheet and pellet were least among water samples. Weight distribution of MPs types also exhibit that fibers were dominated in water. MPs were also distributed on the basis of color where blue and white is dominant colors among all. Heavy metals were detected to be in concentrations that are much higher than permitted concentrations of heavy metals in WHO standards and heavy metal pollution index (HPI) estimates that pollution level was dangerous. Accuracy of methods used to analyze was ±3, which proves the validity of the received results. Synergistic relationship between MPs and heavy metals implies that microplastics are vectors in transportation of contaminants, which is dangerous to ecology and human health. Findings from current work provide insight in accumulation, distribution and abundance of microplastics within flowing water. Results offer a scientific foundation of pollution control and environmental management measures in urban water bodies.

Key words: Microplastics, Fibers, Water contaminants, Aquatic ecosystem, Surface water pollution, Environmental impact categories

1. Introduction

Plastics are lightweight, durable, inert and resistance free pollutants which persist in nature for long time. These properties are further reinforced by various factors such as additives, retardants, fillers and stabilizers etc (Amenábar *et al.*, 2024). Fast-paced plastic pollution all over the world is major cause of concern for marine and terrestrialecosystemsm. According to a report by United Nations Environmental Protection (UNEP) that every year 19 to 23 million tons of plastic waste made its way to aquatic ecosystem including rivers, canals, lakes and ocean (UNEP, 2024). Plastic pollution affects natural processes anhabitatsat of locals which have negative

Muhammad Ali, Adnan Noor Shah, Muhammad Nawaz, Salman Ahmad, Jameel M. Al-Khayri, Abdullateef M. Al Saeed, Abbas E. Rahma, El-Sayed A. Badr, Mustafa I. Almaghasla and Hajiyev Sahib Asgar (2026), Integrated analysis of microplastics and heavy metals in the urban aquatic environment, *Global NEST Journal*, **28**(2), 07949.

impact on socio-economic well-being of people. Microplastics (MPs) are small fragments of plastics usually less than < 5 mm in size and invisible to naked eye (Banik *et al.*, 2024).

Primary plastic particles less than 5 mm in size is intentionally produced and used in various skin care products while secondary microplastic originate from primary microplatic's weathering, chemical/environmental abrasions by UV photo degradation, biodegradation, hydrolysis and change in temperature (Ahmed *et al.*, 2023). UV photo degradation of microplastics breakdown the chemical bonding of plastics called fragmentation (Casillas *et al.*, 2023). MPs with micro to nano size present in water bodies adsorb organic matter, heavy metals and toxic compounds. Microplastics also provides conducive environment for the growth of microorganisms, microbial interaction with heavy metals, toxic compounds and wit MPs itself. Biofilm formation and propagation of pathogenic microbes is also important in this environment. Distribution of MPs in different water bodies is due to the presence of nearby landfill site, sewage lines or wastewater treatment plants. Rivers and streams contain fresh water but are the sink source of MPs (Nath *et al.*, 2023).

Microplastics have lethal effects towards zooplankton, which is taken up by fishes as a source of food. Engulfing MPs by fishes not only become part of their body but also adds into food web. Aquatic organisms taken up large quantity of MPs have effect on human beings as estimated in a study that 55000 MPs were ingested by people by consuming animals affected with MPs exposure (Danopoulos *et al.*, 2020). MPs on soil are harmful for terrestrial animals as they travel with air and scatter over large areas on land. Most MPs degrade under UV radiation from the sun from where carbon is released back to the atmosphere. Extremely small sized MPs were inhaled by animals and human beings which retain in body organ through blood circulation and cause mutagenic effects (Gabisa and Gheewala, 2022). MPs taken up by human beings through drinking water is a potential health hazard. World Health Organization (WHO) recommends toxicological level of MPs daily taken up by drinking water is 3 $\mu g kg^{-1} day^{-1}$ of total body weight (Marsden *et al.*, 2019). Phytoremediation, biochar application, composting and green removal are some of the most prominent solutions to remove MPs (Tran *et al.*, 2022).

Presence of microplastic is a great public discussion because it persists in the aquatic environment and becomes part of food chain. As of 2019, 8000 plastic products were made in Pakistan with 0.8 million tons of plastic which contributed to 0.6 million tons of plastic waste makes its way into aquatic ecosystem (Dawn, 2019). According to a study by Irfan *et al.* (2020) 12-35 MPs per cubic meter were detected in the river Ravi. A descriptive microplastic and heavy-metal measurements of the urban canal system can be used to leverage state-of-the-art IoT-based measurements to improve time resolution and data integrity as discussed by Mohandas *et al.* (2025). In another work by Mohandas *et al.* (2025), it highlights how sensor-cloud structures are necessary in evaluating coupled pollutants (microplastics and heavy metals) in urban water bodies, and this implies that related sensor-network models can enhance subsequent monitoring of microplastic-related pollution. Since study contributes to quantifying the abundance and morphology of MPs in an urban canal system along with associated heavy metals and microbial concentration to establish a relationship between HMs, MPs and microbes in a synergistic way therefore, this research work is designed to highlight the abundance and nature of microplastics in Qasimpur canal Multan.

2. Material and methods

2.1. *Sampling sites*

Multan is an ancient city situated along river Ravi in southern Punjab with population of 2.2 million. Qasimpur canal is the major tributary of Ravi river having many discharge points and move across residential and industrial area of Multan city. A sampling point within the urban area provides insights into the impact of human activities, pollution, and infrastructure on water quality. Twenty-four water samples (three samples per selected site) from different locations were collected based on discharge drains from Multan city and addition of effluents into canal from nearby industries. In total eight sites were distinguished from where water samples were collected before monsoon season in May 2024. Mean annual temperature of Multan is 25°C and annual precipitation is 175 mm. Canal also carry sewage water directed towards it from Multan residential area. Deposition of microplastics from canal water is not done because of lining of canal and fast flow of water. Therefore, concentration of MPs in canal water is expected to be higher than normal.

2.2. *Surface water sampling*

One liter of surface water was collected from each sampling point and transferred to clean glass jar previously rinsed with deionized water. Collected water samples were sieved through stainless steel sieve having mesh size of 25, 100 and 350. Filters containing filtrate were then placed in glass beaker which are in direct contact of 33% H_2O_2 at 50°C for 24 hours to degrade organic matter and to avert the growth of microbes. After 24 hours the leftover in sieve was washed with deionized water thrice to remove residual H_2O_2 (Gies *et al.*, 2018). Samples were again washed with deionized water and filtered through filter paper to remove impurities. Washed sample was then dried at room temperature by placing in petri plates and preserving it for further use.

2.3. *Sample processing*

Samples were processed by using flotation techniques having different densities as described by Zhang et al, (2018). Flotation technique is done by making two extraction solutions with one is DI water and other is sodium iodide solution. Higher density microplastics sample were settled down while lower density MPs remain suspended in the extraction solution. MPs were separated on the basis of heavy and light density plastic particles. Suspended MPs were separated in 50 ml glass funnel and rotate at 120 rpm for 2 hours by adding 40 ml deionized water. Side and cap of tubes were rinsed with DI water and centrifuged at 3000 rpm for 10 minutes to help settle down suspended MPs. Supernatant was filtered through whatman filter paper 91 having pore size 11 µm. filter paper was dried at room temperature and stored in sealed petri plates for further use. Repeat the step thrice until no floating material was observed in solution. Heavy density MPs were also separated by the method by using 600 g L^{-1} sodium iodide solution.

2.4. *Observation, identification and quantification of microplastics*

Dry filter paper containing MPs was placed under microscope and evenly distributed on glass slide with brush to avoid overlapping of MPs. After distribution a high-resolution photo was taken to identify the number and type of microplastic on glass slide. Glass slide was then placed in oven for 3-5 seconds at 130°C and subsequently second photo was taken. MPs heating at such temperature change its structure to shiny, transparent and circular while impurities like organic matter, organic fibers and silicate particles remain unchanged. A visible difference was observed by comparing both photos as first one is a reference for size, number and shape of microplastics while second is set reference to determine any organic component in MPs. Microplastics were separated on the basis if they are organic in nature, thickness of fiber maintained throughout its entire length as well as color of MPs is homogenous throughout its length. All possibly identified MPs were separated, measured, counted and categorized into different types on the basis of morphology, weight and color according to the protocol developed by Hidalgo-Ruz et al, (2012).

2.5. *Heavy metal determination and pollution index*

All collected ground water samples were determined for the presence of heavy metals. For this water samples filtered through stainless steel sieve were used. Arsenic (As) was determined by molybdenum blue method As (V) in UV visible spectrophotometer at wavelength 870 nm. Cadmium (Cd) and lead (Pb) were determined by running on atomic adsorption spectrophotometer (ASA) at 228 nm and 217 nm wavelength respectively. To obtain accuracy in results AAS was calibrated with reference standard prior to analysis. Duplicate sampling and triplicate measurement were recorded to minimize error. Results from As, Cd & Pb were subjected to following formula to determine heavy metal pollution index of collected water samples;

$$\mathrm{HPI} = \frac{\sum_{i=1}^{n} \mathrm{WiQi}}{\sum_{i=1}^{n} \mathrm{Wi}} \qquad (3)$$

In equation; n is the total number of samples, sub-index of ith parameter is Qi, ith unit parameter weight is Wi. Value for ith parameter is calculated by using following equation;

$$\mathrm{Qi} = \sum_{i=1}^{n} \frac{\mathrm{Mi} - \mathrm{li}}{\mathrm{Si} - \mathrm{li}} \times 100 \qquad (2)$$

In equation; concentration of ith metal in water sample is Mi while Si is the maximum value for ith parameter. Li is the ideal value.

2.6. *Microbial activity in water samples*

To quantify microbial activity 100 ml of sample was collected and filtered through having membrane having mesh size of 0.45 µm and incubate it in petri dish for 48 hours at 37°C. Colonies for total coliform and *E.coli* were counted under colony counter and expressed as colony per 100 ml of water as suggested by Forbes et al, (2007).

3. Results

3.1. *Concentration and morphology of microplastics in water*

Microplastics particles retrieved from eight water samples collected from Qasimpur canal, Multan were categorized quantitatively. MPs recovery rate (95-98%) during spiking, observation and quantification stage reinforce analytical results validity. Six types of MPs were observed in the water samples i.e., fiber, fragment, foam, granule, sheet and pellet. Among all collected samples fiber ranges between 25±6.0 and 14±5.5 followed by fragment with average of 19±2.0 and 11±2.6. **Table 1** indicates that concentration of foam also ranges between 14±6.2 and 6±2.6. A significant difference was observed between all MPs types which indicate presence of secondary MPs in canal water. Granule, sheet and pellet altogether were within the similar range however their concentration is less in canal water than fiber and fragment (**Figure 1**).

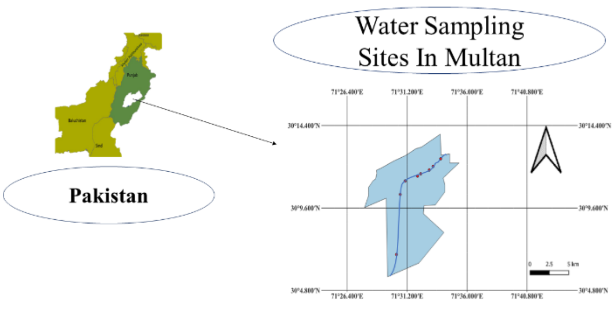


Figure 1 indicates water sampling sites from Qasimpur canal

3.2. *Abundance and distribution of microplastics*

Microplastics abundance in canal water was also recorded as given in **Figure 2**. Fibers were high in concentration with 32% in Disposal Khad factory, 29% in Chawan Pul and 27% in Vehari chowk and Al-Khalid associates. 20% fragment was also recorded in Al-Khalid associates, NGPS, Peeran Ghaib and Naubahar bridge. Foam was ranged between 17-9% while granules were recorded between 21-11%. Sheet ranged between 17-10% while pellet was recorded between 16 and 10%.

3.3. *Microplastics distribution by weight*

Microplastics weight was given in **Table 2** indicating its concentration by weight in water sample. Among all categories fiber ranges between 5.1 mg L^{-1} and 2.4 mg L^{-1}. Fragment also was in the similar range with small variations. Foam, granule, sheet and pellet give highest weight by 3.4 mg L^{-1}, 3.3 mg L^{-1}, 3.3 mg L^{-1} and 3.8 mg L^{-1} respectively. It was noted that MPs size was in correlation with the numbers of MPs identified in water samples.

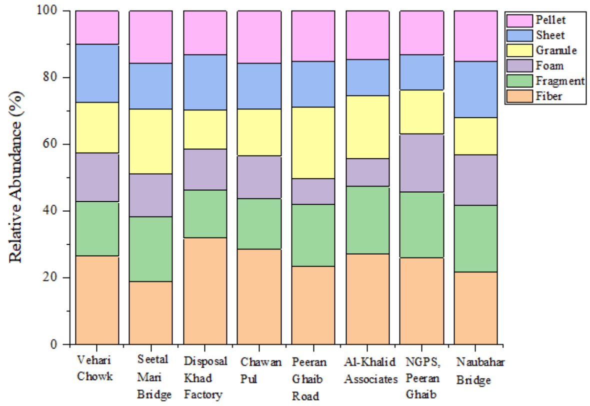


Figure 2 Relative abundance of microplastics (pellet, sheet, granule, foam, fragment, fiber) identified in collected water samples from Qasimpur canal, Multan

3.4. *Microplastics distribution by color*

Identified microplastics were also distributed into various colors as given in **Figure 3**. Among all blue is the abundant color with 52.75% in pellet and 27.08% in sheet. Similarly, white is also dominant color among all with 54.65% in foam as well as 31.25% in sheet. Red and grey colors are also abundant where fiber exhibit 26.04% red color while 31.4% and 31.86% grey color was exhibited by foam and granule respectively. Among all identified MPs fiber, granule and sheet also gives transparent color by 12.43%, 10.62% and 7.29%, respectively. Green and yellow colors are also given by different MPs but in smaller concentration. Off-white and light blue colors are least among all with 8.14% light blue exhibited by foam and 6.59% off-white color is given by pellet.

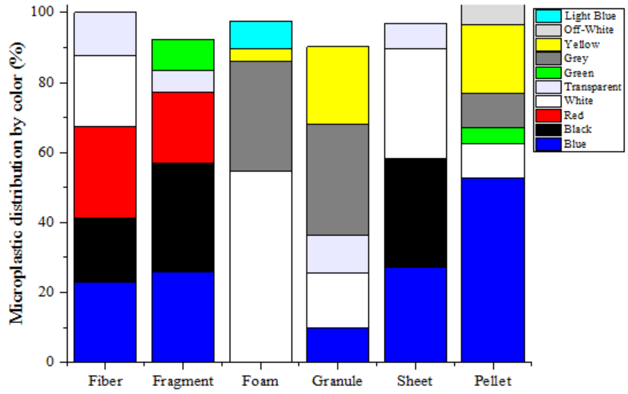


Figure 3. Exhibit microplastics distribution by color

3.5. *Heavy metal concentration and pollution index (HPI) of canal water*

Water samples collected from Qasimpur canal also contain arsenic, cadmium and lead in greater concentration as indicated in **Figure 4a**. Arsenic was recorded between 0.085 mg L^{-1} and 0.062 mg L^{-1}. Cadmium concentration was also recorded between 0.1 and 0.064 mg L^{-1}. Lead was recorded between 0.3 and 0.049 mg L^{-1}. Results indicate that all metals were highly toxic to biotic factors at such concentration. According to World Health Organization (WHO) concentration of As, Cd & Pb were limited in 0.01 mg L^{-1}, 0.003 mg L^{-1} and 0.01 mg L^{-1}, respectively. Heavy metal pollution index indicates cumulative effect of all heavy. **Figure 4b** clearly depicts HPI as hazardous.

Table 1 indicates number of microplastics (mean & standard deviation) detected in 1 liter of collected water samples from Qasimpur canal, Multan

Sampling Site	Fiber	Fragment	Foam	Granule	Sheet	Pellet
Vehari chowk	22±10.5	13±4.5	12±4.3	13±5.5	14±4.0	8±5.1
Seetel Mari bridge	14±5.5	15±4.7	10±2.0	15±4.5	10±5.0	12±4.5
Disposal Khad factory	24±3.2	11±2.6	9±3.0	9±3.6	13±5.6	10±3.0
Chawan Pul	25±6.0	13±2.6	11±7.2	12±4.5	12±3.5	14±5.8
Peeran Ghaib road	19±4.0	15±3.7	6±2.6	17±5.2	11±2.0	12±4.3
Al-Khalid Associates	23±13.0	17±8.5	7±2.0	16±5.5	9±2.0	13±5.6
NGPS, Peeran Ghaib	21±6.0	16±6.0	14±6.2	11±7.0	8±3.2	11±7.7
Naubahar bridge	20±5.5	19±2.0	14±3.7	10±3.2	16±1.5	14±3.0

Table 2. indicates microplastics weight (mean & standard deviation) detected in 1 liter of collected water samples from Qasimpur canal, Multan.

Sampling Site	Fiber (mg L^{-1})	Fragment (mg L^{-1})	Foam (mg L^{-1})	Granule (mg L^{-1})	Sheet (mg L^{-1})	Pellet (mg L^{-1})
Vehari chowk	2.4±1.4	1.5±2.5	2±0.5	2.1±1.1	1.8±0.6	3.8±1.2
Seetel Mari bridge	3.8±0.3	4.8±0.8	2.7±1.1	2.5±1.3	2.3±0.5	3±0.7
Disposal Khad factory	4.9±1.5	2.4±1.4	1.5±0.4	1.9±0.4	3±0.6	2.6±0.5
Chawan Pul	5.1±2.0	4.7±1.2	0.7±0.5	1.8±1.2	1.7±0.4	1.8±0.1
Peeran Ghaib road	4.2±2.0	3.1±2.2	1.6±1.4	1.1±0.3	2.2±0.3	2.1±0.5
Al-Khalid Associates	3.3±0.5	5.5±1.3	2.8±0.9	3.3±1.4	1.9±0.2	3.4±1.2

NGPS, Peeran Ghaib	2.7±2.2	2±2.0	3.4±1.6	2.4±0.6	3.3±1.1	1.7±1.0
Naubahar bridge	3.1±0.6	1.8±1.1	2.9±0.3	1.8±0.6	2.6±1.0	1.6±0.1

3.6. *Microbial concentration of canal water*

Water having high bacterial activity of total coliform and *E.coli* is considered contaminated water due to pathogenic attributes of both microbes. According to WHO both microbial communities must be 0 colony forming unit (CFU) in 100 ml of water. As canal water contains organic matter and heavy metals thus it becomes the active source for the growth of pathogens like coliform and E. coli. Highest total coliform concentration was reported in water sample collected from Naubahar bridge (2290 CFU). Disposal Khad factory and NGPS, Peeran Ghaib also have highest total coliform concentration. On the other hand, *E. coli* concentration in canal water was also similar but with a slight decline compared to coliform concentration. Highest E.coli was noted in NGPS, Peeran Ghaib (1971 CFU) along with Vehari chowk and Naubahar bridge as depicted in **Figure 5**.

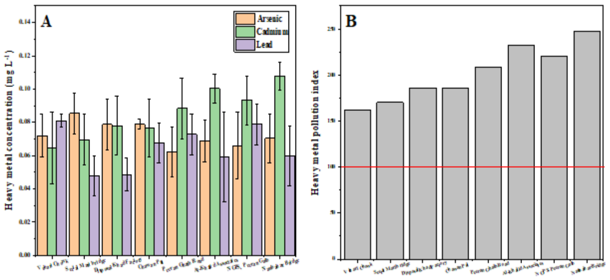


Figure 4 indicates a) heavy metal concentration and b) pollution index of collected water samples from Qasimpur canal, Multan

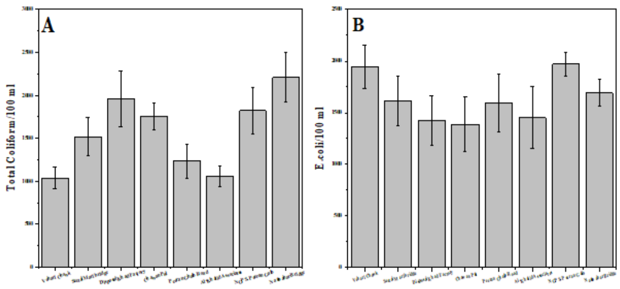


Figure 5 indicates microbial concentration (a) Total coliform & b) E.coli) of collected water samples from Qasimpur canal, Multan]

4. Discussion

Pervasive distribution of microplastics (MPs) with increasing concentration of heavy metal becomes a major challenge for aquatic biodiversity as well as for mankind. Multan is a major industrial city diversified with residential area. With the population of 2.2 million anthropogenic activities greatly impacted Qasimpur canal Multan, contain sewage load from residential areas and effluents from industrial area while flowing all across Multan. Along with it canal also carry water from non-point sources (agriculture runoff). MPs abundance relies on recovery rate as isolation of MPs is a lengthy process involve sieving and centrifugation for couple of time. Moreover, microplastics have more resemblance to organic matter as in case of fiber which might be organic fiber instead of polymeric fiber. Microplastics might also discard away during transportation; sieving and centrifugation by sticking with the walls of glass wear or adhere to the sieve. All mentioned scenarios and hurdles were described by Stolte *et al.* (2015) indicating positive correlation to current work. According to Imhof *et al.* (2012) all above-mentioned described method only gives recovery rate of 81-99%. To improve MPs recovery rate spiking must be done which alternatively improves extraction of MPs during the process as discussed by Simon *et al.* (2018).

Current study is not sensor-design-oriented, but the principle of enhancing precision of measurements is the same as increasing the accuracy of quantifying microplastic particles and related concentrations of the heavy-metal as in future studies, similar signal-processing or sensor-calibration techniques can be applied to microplastic imaging or detection (Palani *et al.*, 2023). Counting of microplastics after separating it from canal water by using different sieves of various mesh sizes is an important task. Usually in sieving there might be a risk of contamination from external environment as it is a long process. Micro and nano fibers present in lab environment might got mix up with the MPs present in the sieves. According to Rochman *et al.* (2015) strict monitoring is applied while conducting the procedure. This involves avoiding suspected MPs from lab environment. On the day of experiment suspected MPs were separated from lab environment on the basis of color and visual appearance. MPs from lab coat or lab wears were separated from the collected samples. Number of MPs after each crucial step i.e., collection, transportation, storage, centrifugation and filtration will be reduced (Talvitie *et al.*, 2015). Loss of fiber of any length is a major drawback to studying MPs. Similar had happened in the current case where number of MPs after each crucial step reduces making it harder to quantify MPs in canal water sample. At the end of procedure, the number of fibers in canal water sample varies between 14 and 25 MPs L^{-1}. Flotation method used in current work followed by centrifugation is widely accepted method to quantify MPs from water. Current MPs separation technique is also superior in case of flotation where higher density MPs settles down leaving behind only less density MPs suspended in the solution as described by Hernandez *et al.* (2017). MPs extraction using oil-water emulsion was given by Crichton *et al.* (2017) but was not applicable as emulsion remains up lift MPs due to which sedimentation and separation on the basis of densities is not possible. Another drawback in the technique is loss of MPs by sticking with sieve.

MPs concentration in surface water is directly attributed to population density and urbanization (Kataoka *et al.*, 2019). Similar situation was described by Irfan *et al.* (2020) where MPs in water samples of river Ravi was largely from municipal and industrial waste. Different types of MPs were isolated from canal water including fiber, foam, granule, sheet, fragment and pellet. Present study describes fiber as most pronounced morphotype in all sampled water collected from various locations of Qasimpur canal, Multan but same was not happened in every case as MPs distribution is based on lab environment and usage pattern (Mason *et al.*, 2016). Microplastics type is also relies on retention in the solution on the basis of density. In some cases, MPs was sorbed into bigger plastic particle and was not able to detect (Michielssen *et al.*, 2016). MPs distribution on the basis of color suggests inherent color of MPs or it might be changed due to weathering or adsorption of chemicals when exposed to contaminants present in wastewater. Discoloration of MPs also happened due to sorption of various pollutants. Predominant blue color in fibers, high percentage of white foam and red dominance in pellet is in consistence with prior studies. According to a study by Jendanklang *et al.* (2023) almost 45% blue fiber, white fiber and pellet with most of them red in color were isolated from Chao Phraya River in Thailand. Similarly, sludge from wastewater treatment plant in Lithuania reports black, white and transparent color in higher frequency while green and red were in minor proportion (Uoginte *et al.*, 2022).

Tail risk contagion and multiscale spillovers as given by Zeng *et al.* (2025) is an effective analogy to the dynamics of environmental pollution. Just as banks running on shocks in a financial market, sharp increases in microplastic or heavy metal loads may spread across related aquatic systems, producing the effect of multiscale contamination. Such spillovers or contagion frameworks may be useful in determining the transmission of risks of pollution among sites and periods in time to aid in predictive management of urban water quality. Similarly, the heterogeneity of interaction between microplastics, heavy metals, and microbes in the water bodies also exhibits varying responses to varied contamination loads. The implementation of quantile-based analysis frameworks may thus enhance the determination of ecological risk along the different pollution gradients (Zeng *et al.*, 2025). Industrialization and urbanization in combination degrade environment. Wastewater having high density heavy metal is hazardous to all type of life. A negative imbalance was developed with the increase in wastewater compared to fresh water (Hussain *et al.*, 2019). Highest concentration of arsenic, cadmium and lead was observed in water samples collected from Qasimpur canal. In Pakistan canal water is the major source which is polluted by industries and sewage water while farmers are forced to apply water for irrigation purpose. Heavy metal concentration depends on environmental condition. As water samples for current study is collected between January and July, varied concentration was observed. MPs have potential to sorb HMs but might take decades or even years to complete the process. Lead is not sorbed in MPs and persists in environment for long time. Heavy metal pollution index is determined for all collecting points' revels that water is hazardous for all kinds of activities. Local factors like sunlight, flow of water and presence of organic content also impacted on the presence of HMs in water thereby affect rate of HPI (Zhou *et al.*, 2019). Pathogenic microbes such as Coliform and E. coli were determined in water sample of Qasimpur canal. According to Ashbolt *et al.* (2001) the most probable reason behind concentration of these two microbes is the presence of feces in water samples. It has also been suggested that estimation of these microbes is necessary to indicate its presence in wastewater (Sanders *et al.*, 2013). It has also been reported that estimation of coliform is an easy task due to its interaction with the ecosystem to produce hazardous result as estimated by Khan *et al.* (2019). Microbe oxidation and membrane separation are predominate technique in microbial separation. Current study reveals that high microbes were noted in water samples collected from NGPS, Peeran Ghaib, Disposal Khad factory and Vehari Chowk.

5. Conclusion

Current study was framed to get distribution, concentration and types of microplastics in the water samples of Qasimpur canal, Multan along with adapted separation technique. Flotation technique proved to work best in terms of separating MPs in water samples. It was noted that MPs near urban centers and industries were high in concentration. Detection method for MPs helps separate organic and polymeric micro particles in water samples. Among all isolated MPs, fibers were prevalent to all water samples while pellet were least in water samples. Heavy metals (As, Cd & Pb) were detected in water samples giving varying concentration. Heavy metal pollution index was calculated giving hazardous nature of water for all collected water samples. Due to surface water microbial concentration is highest largely came from sewage water containing fecal components. Results suggest that MPs might act as vector in transferring heavy metals over the large area along with movement of water in canal. Synergistic pollution of MPs and heavy metals poses ecological risk and potential harmful effect to aquatic organisms. The number of sampling seasons used in study was restricted to one canal and one season which might not reflect the changes with time in contamination. To enhance accuracy, future studies must cover a multi-seasonal period, have a larger area of coverage and utilize advanced spectroscopic or Internet of Things-based methods of detection. The inclusion of predictive modeling might also help improve the knowledge about microplastic/heavy metal interactions and their ecological effects in the long run.

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