

Microplastics Invasion in Freshwater Ecosystems of Coimbatore, Tamilnadu: A Study on Water, Sediment and Fish Species of Five Major Lakes

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Received April 14, 2023; Revised May 17, 2023; Accepted May 29, 2023

Abstract The purpose of the current study was to assess whether the freshwater ecosystems of Coimbatore are polluted with microplastics, quantify the amount of microplastics in these freshwater ecosystems by analysing the water, sediment and fish samples from five major lakes and thereby providing baseline data on the microplastic pollution status in freshwater ecosystems of Coimbatore. All the studied lakes were polluted with a considerable amount of microplastics identified in water, sediment and fish samples. Sediment samples had more microplastics than water and fish in all lakes except one. Fifteen different polymer types were identified from these extracted microplastics, which included common polymers such as PP, PVC, PET, etc. and also polyisoprene, polysulfone, cellulose nitrate, etc that are not commonly identified in previous literatures, which are mainly used for the production of N95 masks, surgical gloves etc. This justify their presence as our sampling period was post-covid. In fishes, microplastics were identified in gills, gastrointestinal tracts and flesh. The presence of microplastics in the edible tissues of fish heats up the risk of microplastics entering humans via the food chain.

Keywords: Microplastic pollution, freshwater ecosystem, ATR-FTIR

Cite This Article: Haritha Thulaseedharan Nair, and Siddhuraju Perumal, “Microplastics Invasion in Freshwater Ecosystems of Coimbatore, Tamilnadu: A Study on Water, Sediment and Fish Species of Five Major Lakes.” *Journal of Environment Pollution and Human Health*, vol. 11, no. 2 (2023): 21-32. doi: 10.12691/jephh-11-2-1.

1. Introduction

More research interest in microplastics (MPs) is ascribable to their longevity, which enables their distribution to a long distance from their source and accumulation in different ecosystems with minimum anthropogenic interactions including polar regions. In the early phases of microplastic pollution studies, more importance was given to the marine environment. Since the freshwater ecosystem is an easier pathway of MPs to humans (freshwater bodies, drinking water supplies) now, freshwater ecosystems are also given importance. A higher percentage of MP contributions to marine systems are from land [1] and inland freshwater systems [2], but less research has been conducted for quantifying the amount and threat of microplastics in inland water systems.

Due to biological and chemical stressors, the plastic waste that is dumped in freshwater sources breaks down into tiny particles [2] that are known as microplastics, which are defined as particles with a size between 0.1 mm and 5 mm [3]. Microplastics appear in a range of shapes, including fragments, fiber, beads, foams, pellets, and film [3,4] which could be made up of different polymer types.

Several studies confirm that the major sources of MPs to freshwater are through, the usage of cosmetics and personal care products, abrasion of household plastics, laundry, tyre wear, fishing, etc. [5] which indicates most of the sources are from the daily human activities.

The aquatic organisms often get confused with the size, shape and different colors of microplastics with their food leads to ingestion of these tiny plastic particles [6] or accidentally ingest with food intake and also through the gills of fish during respiration/water exchange [7]. This results in intestinal damage, oxidative stress, affects survival and metabolism, etc. in freshwater fauna [8,9].

The haste of microplastic contamination throughout the globe is much faster than any other kind of pollution witnessed so far. When the cases of microplastic pollution were identified in different ecosystems, such a rapid invasion of this tiny pollutant into higher food chains and humans was not expected. Now it's everywhere, in our waters [10], our foods including drinking water [11,12] edible salt [13], recently identified in human breast milk [14,15] and even in human placenta [16]. These studies solidly validate the fact that microplastic pollution is expanding very rapidly everywhere, which should be stopped immediately to reduce its further spread.

Very few research has been conducted in India, particularly in freshwater sources, when compared to the microplastic studies that have been conducted throughout the world. Moreover, in the studies carried out in India, little to no attention is given to aquatic biota, and researchers highlighted the need for a follow-up study on the freshwater fauna to obtain a complete picture of the microplastic pollution in the specific freshwater ecosystem [17,18].

Hence, the present study is proposed and it focuses on identifying the intensity of microplastic pollution in five major lakes of Coimbatore, Tamil Nadu by quantifying the microplastics in water, sediment and fish population of the lakes. No study, to date, has addressed the presence of microplastics in these lakes. Thus, the study will provide baseline data on the microplastic contamination of these freshwater sources which may create a new research avenue and reference for future studies.

2. Materials and Methods

2.1. Study Area

The Coimbatore district is located between 10°55' and 11°10'N and 77°10' and 76°50'E, is around 470 meters above sea level, in Tamil Nadu state, India. Wetlands in Coimbatore have already been investigated for their water quality, flora, biodiversity, and bird populations [19,20]. So, we have selected our study areas in which fewer studies have been conducted, their pollution status and usage by people for fishing and other domestic purposes. We have studied five lakes in and around Coimbatore namely Krishnampathy Lake (11°00'27.9"N 76°55'34.7"E), Sengulam Lake (10°57'07.8"N 76°56'28.0"E), Pallapalayam Lake (10°59'47.2"N 77°04'54.1"E), Vellalore Lake (10°58'26.7"N 77°00'27.4"E) and Irugur Lake (11°01'08.5"N 77°04'37.2"E). Local population depends on all these lakes for their livelihood such as agriculture, farming and fishing hence making these sites an important area for pollution studies.

2.2. Sample Collection

Water and sediment samples are collected from the five lakes. For microplastics examination, 10 liters of water from each lake were filtered using a set of stainless-steel sieves (5 mm, 3 mm and 1 mm) stacked one above the other from the field itself. These sieves are later covered using aluminium foil to avoid contamination and brought to the lab which is later washed off with distilled water and the residues in the sieves were collected into a glass bottle for further analysis [21]. Sediment samples (2 kg from each lake) were collected using grab sampling equipment Van-veen Grab and transported to the lab for further analysis. Fish samples (*Oreochromis niloticus*) were collected from all five lakes (9 fishes from each lake) with the help of local fishermen. The fish species (*Oreochromis niloticus*) was a common species in all the five lakes and was frequently used by the nearby inhabitants as food source. Also *O. niloticus* feeds around the midlevel and bottom level of water, hence its feeding habit covers most areas of the lake and thus strengthens the data on microplastics in fishes.

2.3. Sample Treatment and Extraction of Microplastics

To prevent any contamination, the laboratory apparatus and glassware were properly cleaned with double-distilled water, and the digestion operations were carried out in a laminar airflow chamber. No plastic materials were used during the work and cotton lab coats were worn.

2.4. Sediment

Wet sediment samples were dried in a hot air oven at 50°C. The dried samples were then sieved through 5 mm mesh and larger debris was removed. Extraction of microplastics from the soil is done using a combined and modified method of [22] and the National Oceanic and Atmospheric Administration (NOAA) protocol [23].

Subsequently, 50g of sediment sample were subjected to density separation using saturated NaCl solution. 200 ml of 5 M NaCl solution was added to the sediment sample, stirred for 20 mins at high RPM and left to settle for 6 hours. The supernatant of the settled solution was then transferred to a density separator and left overnight. The supernatant from the density separator was then filtered using Glass microfiber filters (Grade-GF/A, Himedia) using a Vacuum filtration unit. The filter papers were then dried and the residues were subjected to wet peroxide oxidation (WPO) process using 30% hydrogen peroxide, which will separate the microplastic particles from organic and other debris in samples, making it possible to visually count and separate microplastics. After digestion, the WPO mixture was again treated with NaCl density separation and left the density separator overnight covered with aluminium foil. The supernatant was then filtered same as the above. The filter paper was placed and covered with petri plates to avoid airborne contamination dried and saved for microscopic examination.

2.5. Water

For the water samples, microplastic identification is done using National Oceanic and Atmospheric Administration (NOAA) protocol [23]. The filtrate from the sieve is carefully collected and subjected to wet peroxide oxidation (if more organic matters are present), and the residue is filtered by Glass microfiber filter (Grade- GF/A, Himedia) using a Vacuum filtration unit. Filter papers are then dried and saved for microscopic examination.

2.6. Fishes

The collected fish samples were carried to the lab for further processing. For each sampling site, the fish caught were divided into three groups for triplicate analysis. Microplastic examination was done in the gills, Intestine/gastrointestinal tract and flesh of all the fishes. Using clean scissors and forceps the gills and gastrointestinal tracts of the defrosted fishes were removed, dissected and examined under a dissection microscope for any visible microplastics [24]. The dissected gills, gastrointestinal tracts and flesh were soaked in 10% potassium hydroxide solution in glass bottles and incubated at 55°C for 48-72 hr or till all the organic debris was digested. The digested

solution was then filtered and processed the same as the water samples and filter papers are saved for microscopic examination [25,26].

2.7. Microscopic Examination

The microplastic particles extracted from the samples were identified using a trinocular microscope equipped with a camera (Weswox Optik Digital Research Microscope, India) at 4X magnification. The particle size, shape, and color were identified using the microscope, and photographs were taken for each particle.

2.8. Polymer Identification

Polymer types of microplastics were identified using Attenuated Total Reflectance-Fourier transform infrared (ATR-FTIR) spectroscopy. A subset of extracted microplastics was used for polymer characterisation. The FT/IR-4700 type A (Jasco, Japan) was used for the study. Spectra from 4000 cm^{-1} to 500 cm^{-1} were collected at 4 cm^{-1} resolution. The absorption bands of the resultant spectrum are compared with polymer spectral libraries and early literatures.

2.9. Data Analysis

The abundance of microplastics in water is expressed as the number of particles per litre of water and in sediments as the number of particles per kilogram of sediment. In fish, the data is presented as microplastic per fish. All the values expressed are means of triplicate determination $\pm$ standard deviation. All the data were subjected to one-way analysis of variance (ANOVA), and the significance of differences between means was determined by Duncan's multiple-range test ($P < 0.05$) using SPSS (version 21, SPSS Inc., Waker drive Chicago, USA).

3. Results and Discussion

3.1. The Abundance of Microplastics in Water and Sediment

The presence of microplastics was confirmed in all five lakes in both water and sediment samples. Out of which, the abundance of microplastics were maximum observed in Sengulam lake (30.34 %) in both water ($24.66^a \pm 6.02$) and sediment ($30.66^a \pm 3.51$) sample followed by Irugur lake (25.41%) for sediment ($26^b \pm 10.14$) and water ($20.33^b \pm 2.51$). Pallapalayam lake (15.72 %) had the next highest abundance of MPs in sediment ($15.33^c \pm 4.72$) but Vellalore lake (14.80 %) water ($14.66^c \pm 3.05$) had more microplastics than in water samples ($13.33^d \pm 4.72$) of Pallapalayam lake. Krishnampathy lake (13.71%) accounted for the least number of microplastics in water ($11.66^d \pm 3.05$) and Vellalore sediment ($12.33^d \pm 4.5$) contained least number of MPs in sediments out of all the sampling lakes. In all the sampling sites except Vellalore, sediment had more microplastic presence than water samples. Since lake waters are stagnant and have a very less flow rate/flow velocity, there will be more chances of MPs presence in sediment than in water. These results corroborate the claims made by [27,28] that flow

patterns, such as low flow times, were crucial in the formation of microplastic accumulation "hotspots" in freshwaters. When microplastics are discharged into aquatic environments, they might be suspended in the water column or sink to the sediment depending on their density, hydrophobic nature, composition and shape [29]. The density of microplastics increases as a result of attachment to their surfaces by clay minerals and/or biota, resulting in sinking [30]. All the microplastics observed in sediment samples had clay/soil attached to their surfaces. All the lakes are closer to domestic inhabitation (residential areas) leading to the discharge/accumulation of domestic waste into the lakes. Both Krishnampathy and Irugur lakes were adjacent to agricultural fields and all the lakes had fishing facilities which are significant microplastic sources. The elevated presence of MP has been associated with areas of high anthropogenic impacts.

3.2. The Abundance of Microplastics in Fishes

Fishes collected from all the lakes had presence of microplastics in them. Out of the total fishes sampled from all five lakes, 73.3 % of the fishes had microplastics in them. The total number of plastics identified was higher in Sengulam lake samples and least in Vellalore lake samples. The comparative account of the abundance of microplastics in water, sediment and fish of all the lakes were depicted in Figure 1.

In all the fishes, the gastrointestinal tract (GIT) and gills had MPs present in them, whereas only a single fish from site Pallapalayam lake had traces of MPs in flesh (which was below the size 0.1 mm). Out of the total microplastic present in the fishes, 63.93 % was present in GIT, 34.42 % in gills and 1.63% in the flesh of the fishes. When compared to studies on microplastic identification in the intestine and gills, its presence in fish edible tissue/flesh is relatively understudied. In most places, the GIT and gills were removed before human consumption, so MPs in fishes were not considered a food safety issue until recent studies revealed the presence of MPs in edible tissues [31].

Numerous studies have proposed mechanisms of translocation of microplastics in edible muscles via endocytosis and perception [32,33,34]. The topic is under debate among researchers, and it is still unclear exactly how particles $> 100 \text{ nm}$ are translocated to tissues [35,36]. In addition to the aforesaid mechanisms, adherence has been shown to be a potential pathway for microplastic presence in edible tissues [37]. In a recent study, the total amount of microplastics found on fish skin exceeded that found in their gills and guts, indicating that the adhesion of microplastics to fish skin is a significant source of contamination for fish [38]. This becomes relevant when considering the fact that, particularly in India small fishes are often eaten without the skin being removed. The risk of bioaccumulation and biomagnification of these tiny particles along the food chain couldn't be overlooked. In a recent work the occurrence of MPs along the food chain in a river and pond ecosystem disclosed that the air, water, sediment, plankton, fish and avian species of those particular ecosystems were polluted with MPs which indicates some degree of bioaccumulation of these pollutants in the ecosystem [39].

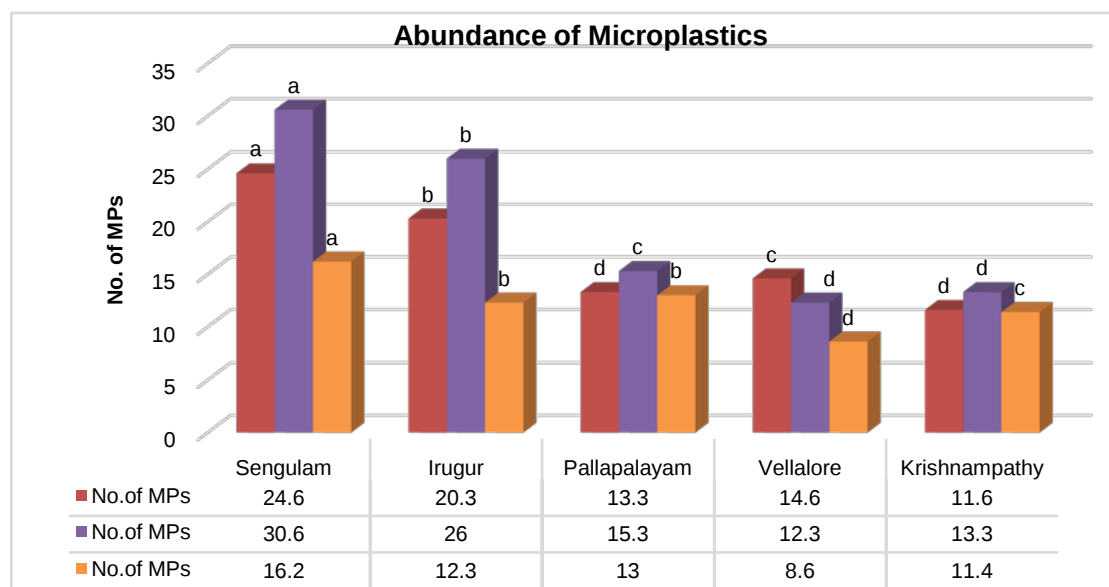


Figure 1. Comparative account of the abundance of microplastics in water, sediment and fish of all lakes

3.3. Morphological Characteristics of Identified Microplastics

In both water and sediment samples, plastic particles with different sizes and morphology were observed. Most of the microplastics observed seemed to be secondary in origin, ie; they were found to be degraded from macroplastics. From all the water, sediment and fish samples analysed, four major shapes of plastics were identified, they are Fragment, Fiber, Film, and Foam. On the whole, Fragment (38%) was the most abundant shape followed by Fibre (33%), Film (27%) and Foam (2%) with the least count. In the case of the water sample, the relative proportion of Fibre was highest whereas in sediment samples fragment-shaped plastics were more in count. Comparable relative dominance of fiber in water is also observed in similar works [40,41]. Another study in an Indian river in Bangladesh also found higher fibrous-shaped microplastics in water samples [42]. This may be due to the lightweight of fibers when compared with fragments. But different trends of microplastic dominance were also observed in another study in an Indian river in Bangladesh itself [43]. These differences could be merely because of the difference in the plastic debris accumulated and the anthropogenic activities in the rivers which differs between places.

In the fish sampled, the major shape of plastics identified was fiber (68.76 %) following fragment (31.24 %). Some other irregular shapes were also observed in fish samples (in flesh and Intestine) which were actually in nanosize and due to difficulty in processing and size not within the size range of the current study, we neglected the same. The relatively smaller size of MPs in flesh/muscles compared to gills and GIT is in concordance with the findings of earlier studies [31,44]. In gills, we could observe only fibrous-shaped microplastics and in the Intestine both fibrous and fragment-shaped MPs were present. The dominance of fiber shape in fishes could be because they keep floating on and below the water surface more than settling which increases their chance of being ingested and also exposed to gills via

breathing. The feeding habit of the fish species *Oreochromis niloticus* we selected also complies with the results observed. These fishes feed almost everywhere including the mid and bottom levels of the water with a variety of foods including both plant and animal food [45]. Additionally, as fibers are more likely to attach to intestinal walls than other types of MPs, difficulty in elimination through feces may be a contributing factor to the higher fibre content in the intestine [41]. The shape distribution of microplastics in all the samples were depicted in Figure 2.

The colour of MPs is not a secondary issue in their hazard to aquatic life because colour influences how they interact with aquatic organisms, some colours appear to alter their ability to discern between plastics and natural food [46,47]. MPs are ingested by aquatic creatures alongside their food, tricked by their size and colour; indeed, minute plastic fragments have been found in a variety of species and at all stages of the aquatic food [48].

Out of the all-plastic particles collected, 22% were in a transparent/light color. Some of these transparent particles seemed to be that they lost their original colour due to abrasion from water, soil and other factors. Transparent plastics were seen both in water and sediment. These were mostly in the shape of film and fragments. The next abundant color was white (20%) and these were identified in shapes of film, fragment and fiber. Blue (19%) colored plastics were next to white colored in abundance. Blue-colored plastics were observed in all shapes. Light brown (17.2%) colored plastics were more observed in sediment and were in the shape of fragments and film. Green (10.4%) colored plastics were observed in both water and sediment and Red (8.6%) colored was observed in water samples. Some other plastic particles with some mixtures of colors were also identified, which are categorized as others (2.8%).

In fishes, the major color identified was blue (53.32 %), followed by green (25.55 %) and red (21.13 %) in percentage. Green-colored plastic particles resembled algae/zooplankton, which might have the potential to be ingested by aquatic organisms. And the species

selected in the study (*Oreochromis niloticus*) is found to be omnivorous [49] and more green algae were found to be fed by the species in a study [45]. In a recent laboratory study, they observed that the fish ingested three times more plastics when offered together with food and also, they ingested colored plastics more than white plastics particularly yellow and blue [50], which is evidenced by the present study, in which the microplastics extracted from the fishes sampled were blue, green and red colored plastics. The color distribution of microplastics in all the samples collected were depicted in Figure 3. And the microscopic images of microplastics collected from water, sediment, and fish are shown in Figure 4.

3.4. Polymer Characterisation of Identified Microplastics

Both primary and secondary microplastics reach the environment through several pathways. During field sampling, we observed lot of plastic wastes, both micro and macro plastics in the sampling sites. Fifteen different polymer types were identified in the microplastics extracted from all the samples: Polypropylene (PP), Polyvinyl chloride (PVC), Polystyrene (PS), Polyethylene

tetraphthalate (PET), Cellulose nitrate, Rubber, Nylon, Polyvinyl Alcohol, Polyvinyl Acetate, Polyisoprene, Polyhydroxy butyrate (PHB), Polycarbonate, Polysulfone, Cellulose, Polymethyl methacrylate (PMMA). The absorption bands used to identify each polymer is given in Table 1 and ATR-FTIR spectrum of the identified polymers are given in Figure 6.

The polymers PP, PVC, PS, PET, Rubber, Polycarbonate, Nylon were expected to be found in the samples collected, as these are common polymers manufactured and used for daily activities, but others such as Cellulose nitrate, PMMA, PHB, Polyisoprene, Polysulfone, etc were not commonly reported in similar studies. Comparisons with previous literatures couldn't be interrelated as the anthropogenic as well as other activities associated with particular study areas will have an impact on the polymer types identified. Entirely in all the samples, PP was the highest in number, followed by Nylon and PS. In water and fish samples also, the same trend was found except PS was higher than Nylon in number in water samples. In sediments, PVC was higher, followed by Cellulose and PMMA. The abundance of different polymers identified from all the samples and also exclusively in water, sediment and fish is shown in Figure 5.

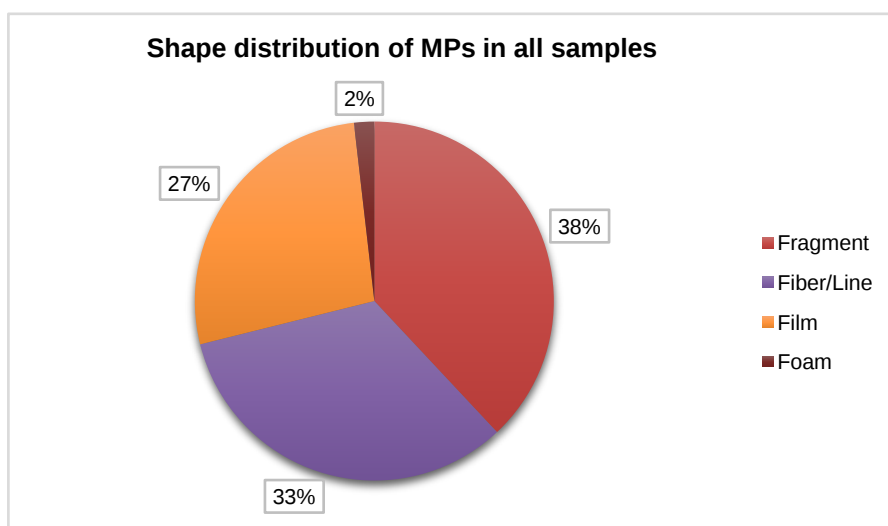


Figure 2. The shape distribution of microplastics in all the samples

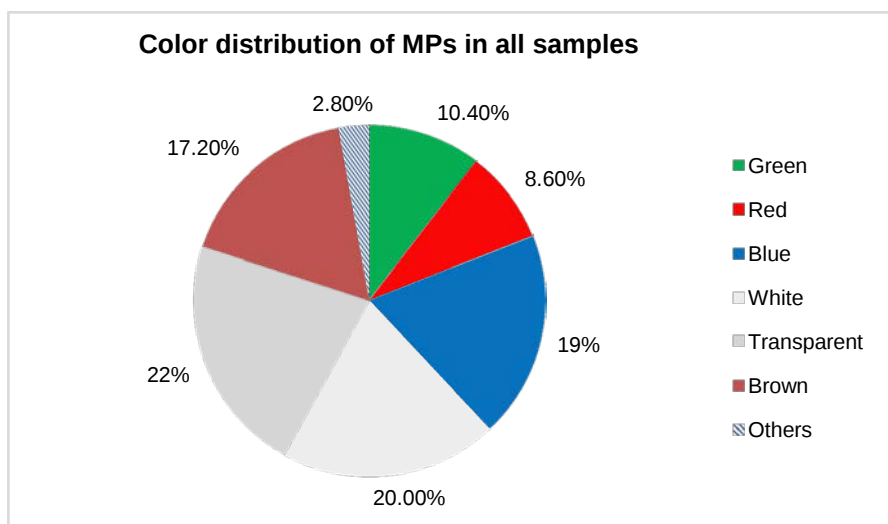


Figure 3. The color distribution of microplastics in all the samples

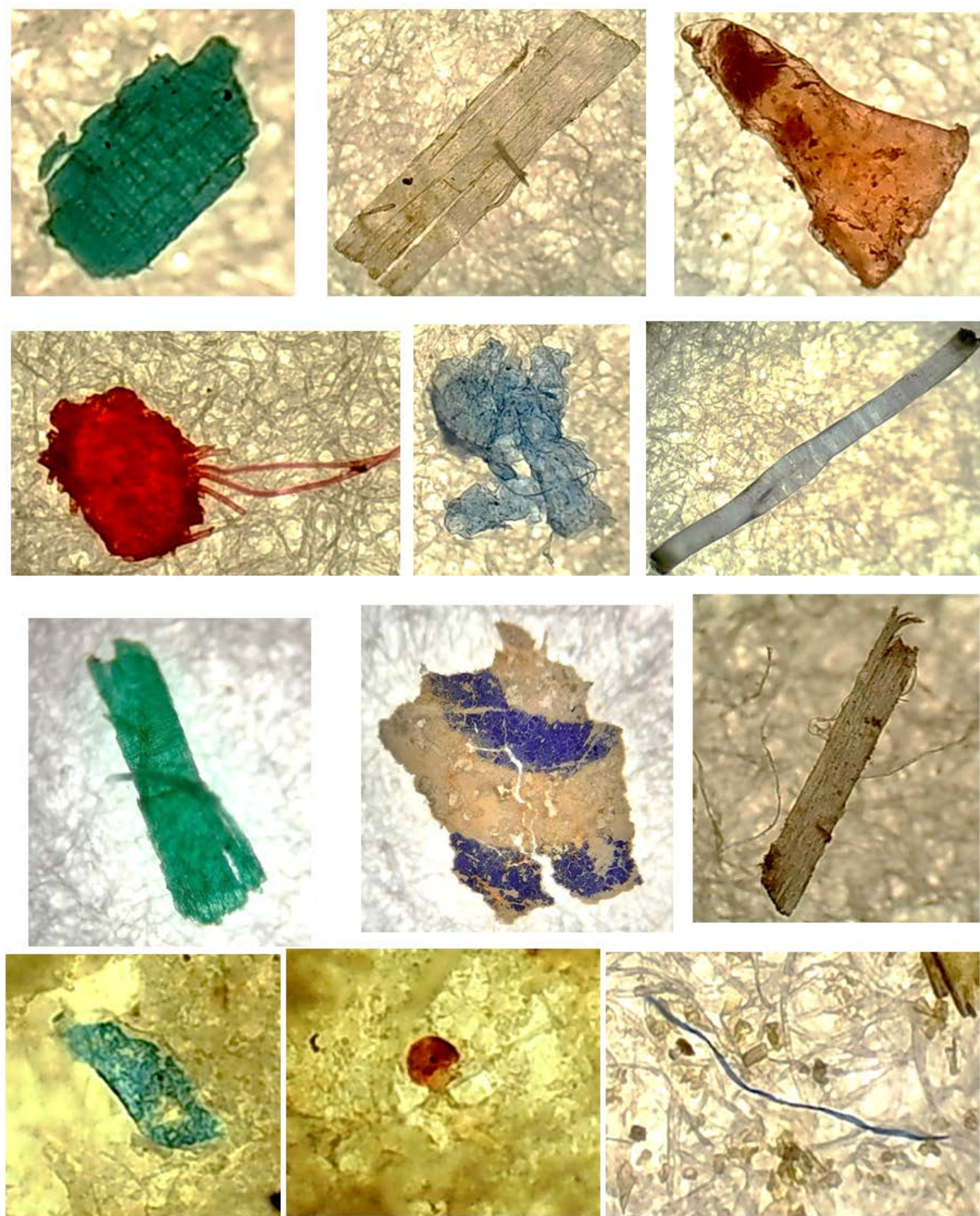


Figure 4. Microscopic images of collected microplastics from water, sediment and fishes

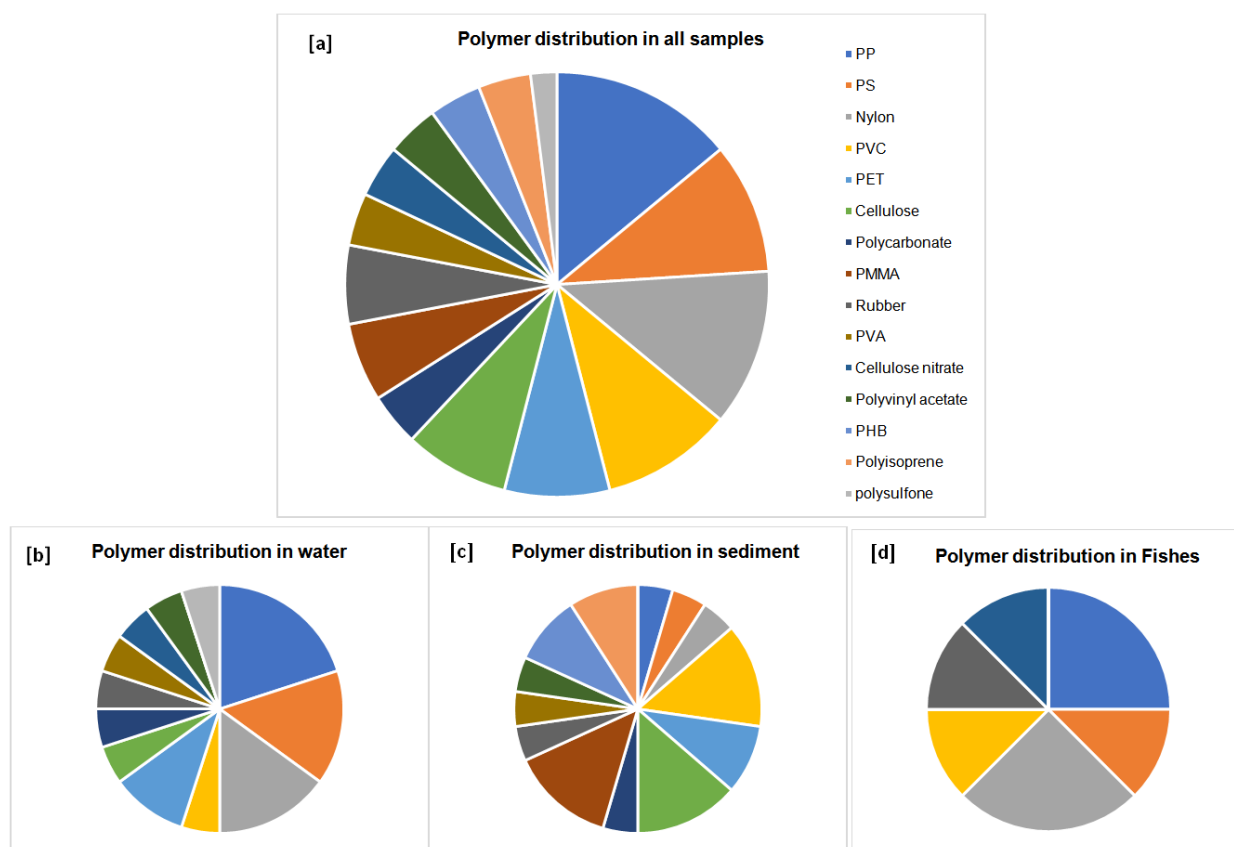
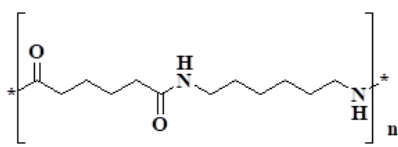
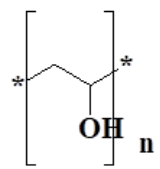
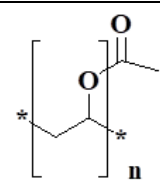
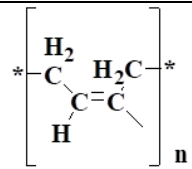
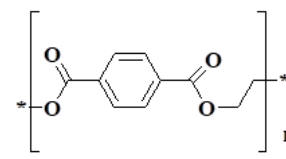
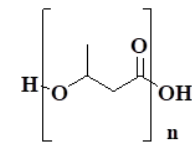
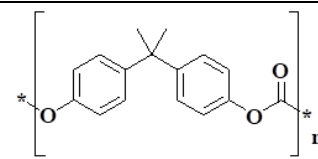
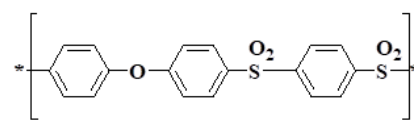
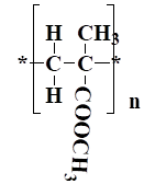
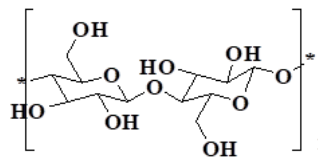


Figure 5. [a] Polymer distribution in all samples, [b] Polymer distribution in water, [c] Polymer distribution in sediment, [d] Polymer distribution in fishes

Table 1. The absorption bands of polymers used for the identification

Polymer	Chemical Structure	Absorption bands (cm ⁻¹) used for identification	References
Polypropylene		840 972 1164 1377 1456 2839 2915 2952	[62,63,64]
Polyvinyl chloride		611 965 1078 1278 1424 2964	[62,64,65]
Cellulose Nitrate		830 1125 1646 2850 2926	[64,66]
Rubber		1374 1442 1649 2853 2915 2957	[65]
Polystyrene		679 917 1028 1461 2847 2917 3024	[62,63,64]

Polymer	Chemical Structure	Absorption bands (cm ⁻¹) used for identification	References
Nylon		671 731 934 1199 1340 1465 1537 1633 2852 2935 3294	[62,64,67]
Polyvinyl alcohol		868 915 1025 1095 1324 1420 1650 2936	[62,67]
Polyvinyl acetate		1026 1239 1365 1432 2850 2928	[62]
Polyisoprene		842 994 1125 1333 2849 2936 3030	[62]
Polyethylene tetrathalate (PET)		720 1096 1264 1723 2345	[63,64,68]
Polyhydroxy butyrate		1024 1098 1216 1371 1439 2937 3012	[62]
Polycarbonate		1015 1095 1216 1359 1515 2852 3019	[62,64]
Polysulfone		841 1015 1274 1342 1515 1709	[62]
PMMA		725 964 1158 1251 1384 1589 2963	[63,64]
Cellulose		666 1022 1101 1367 1423 2853 2938	[67]

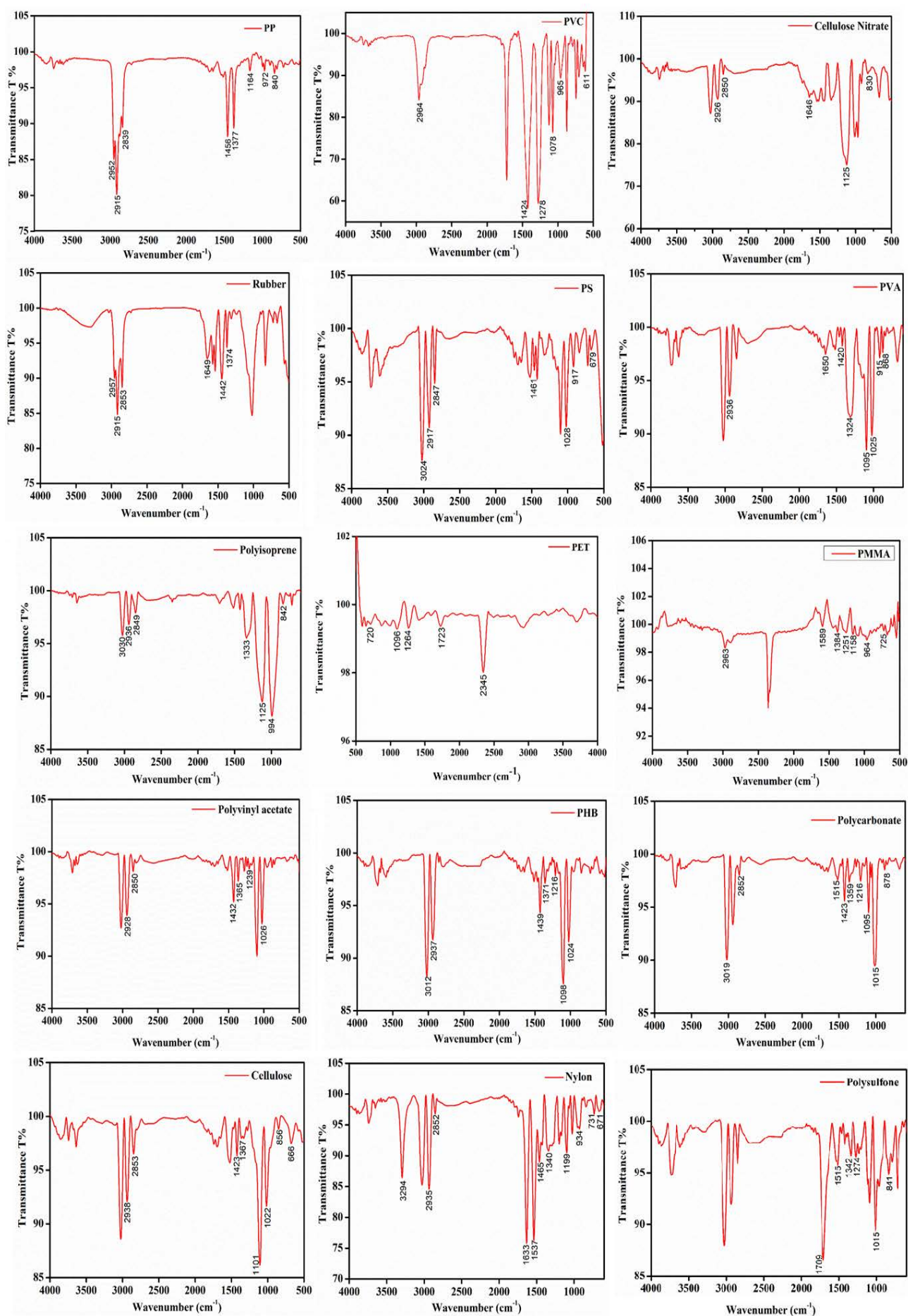


Figure 6. ATR-FTIR Spectrum of identified polymers

PP and PET are commonly used in packaging, bags, ropes, bottles and other daily necessities [21] which were abundant in all the lakes we sampled. Nylon is often used in nets and therefore is associated with fisheries activity [51] which was common in all the sampled lakes and these could be also possibly from bristles of brushes, textiles, automotive, etc. [18] PVC is also a common polymer mainly used for irrigation pipes, electrical/electronic accessories, health care (medicinal packaging, catheters, cannulas), automotive, etc. Rubber is used in different fishing gears, automotive, vehicle tyres, surgical gloves, etc. [5] Rubber, cellulose nitrate, and polyisoprene were commonly used in the manufacture of N95 masks [52] and surgical gloves [53]. Since our sample collection period was after the Covid-19 pandemic, these results give evidence of how the pandemic provided for the microplastic concentration in the aquatic ecosystems [54] and also could be the possible reason for least identification of these polymers in previous studies.

Most of these polymers were already found to be disrupting the growth and metabolism of aquatic fauna. PE, PP and PVC induced oxidative stress and intestinal damage in *Danio rerio* [8], immune system dysfunction and histopathological effects were found in *Dicentrarchus labrax* through the exposure of PVC and PE [55]. As we already discussed several mechanisms pave way for these polymers to the edible and non-edible tissues of aquatic organisms. When it comes to humans through the food chain, the effects of these tiny plastic particles are not much expressed as in fishes because the amount of plastics was not enough to create the same effect on humans as in lower trophic level organisms. A recent study confirmed that exposure of PS micro fragments to human-derived cells increased the production of reactive oxygen species, cell death and inflammation of immune cells. And additionally, when the concentration and roughness of these PS MPs increased, these effects also became more pronounced [56]. Likewise, these microplastics may have an impact on male fertility by degrading sperm quality [57]. The pathway of exposure could be either direct exposure or via the food chain, which is still unclear or under debate, but the presence of these tiny particles was confirmed in various organs or parts of the human body such as liver tissues [58], lung tissues [59,60], human blood [61] etc. These findings imply that long-term exposure to these microplastics can significantly harm human health.

4. Conclusion

Early research highlighted the need for detailed studies on microplastics in freshwater ecosystems of Tamil Nadu including the fauna. In this context, the present study identified the presence and quantified microplastics of freshwater ecosystems of the Coimbatore region, Tamil Nadu with emphasis on fish fauna. The results of this exploratory study report that the freshwater ecosystems of Coimbatore are much polluted with microplastics up to the organism level which could be sooner or later a pathway to humans.

Most of the polymer types identified in the study are directly related to human activities. Also from our direct

field observation, we could identify that the daily usage of plastic materials by humans, domestic discharges and urban runoff were the important sources of MPs in the aquatic environment rather than industrial or large-scale plastic waste disposal. These results raise awareness and further support the link to human activities in the nearby areas highlighting the importance of proper waste management and disposal systems, particularly for domestic and household wastes. 'Source reduction' should be more emphasized during waste management, because once these microplastics are released into the environment, it is a strenuous task to recover them or prevent their further spread.

Even if the majority of wastes were from domestic discharges, the public is not much aware that they are contributing to a large extent to the 'microplastic pollution' as this particular term is not that familiar to a public community like the research community. Likewise, the general public is not at all aware of the potential harm that MPs may cause to the human population, which makes them less cognizant of their role in MPs pollution. So, further research and conveying the research findings to the public through different initiatives are need of the moment to avoid the further spread of these emerging pollutants.

Acknowledgments

The authors gratefully acknowledge the financial support provided by Department of Science and Technology-Ministry of Science and Technology, Govt. of India under INSPIRE Fellowship program (Grant No. IF180788). The authors thankfully acknowledge Department of Chemistry, Bharathiar University, Coimbatore for providing ATR-FTIR Instrument facility. The authors are also grateful to Bharathiar University, Coimbatore, TN, India and DST-FIST and PURSE programs for providing necessary research laboratory facilities.

References

- [1] Andrady, A. L., Microplastics in the marine environment. *Mar. Pollut. Bull.*, 2011, 62(8), 1596-1605.
- [2] Alimi, O. S., Farner Budarz, J., Hernandez, L. M. and Tufenkji, N., Microplastics and nanoplastics in aquatic environments: aggregation, deposition, and enhanced contaminant transport. *Environ. Sci. Technol.*, 2018, 52(4), 1704-1724.
- [3] Lusher, A., Hollman, P. and Mendoza-Hill, J., Microplastics in fisheries and aquaculture. *FAO Fisheries and Aquaculture Technical Paper (FAO)*, 2017, eng no. 615.
- [4] Keerthika, K., Padmavathy, P., Rani, V., Jeyashakila, R., Aanand, S. and Kutty, R., Spatial, seasonal and ecological risk assessment of microplastics in sediment and surface water along the Thoothukudi, south Tamil Nadu, south east India. *Environ. Monit. Assess.*, 2022, 194(11), 1-17.
- [5] Haritha, T.N. and Siddhuraju, P., Trophic Transfer and Accumulation of Microplastics in Freshwater Ecosystem: Risk to Food Security and Human Health. *Int. J. Ecol.*, 2022, Article ID 1234078.
- [6] Galafassi, S., Campanale, C., Massarelli, C., Uricchio, V. F. and Volta, P., Do freshwater fish eat microplastics? A review with a focus on effects on fish health and predictive traits of mps ingestion. *Water.*, 2021, 13(16), 2214.
- [7] Yin, X., Wu, J., Liu, Y., Chen, X., Xie, C., Liang, Y., Li, J. and Jiang, Z., Accumulation of microplastics in fish guts and gills from a large natural lake: Selective or non-selective?. *Environ. Pollut.*, 2022, 309, 119785.

- [8] Lei, L., Wu, S., Lu, S., Liu, M., Song, Y., Fu, Z., Shi, H., Raley-Susman, K.M. and He, D., Microplastic particles cause intestinal damage and other adverse effects in zebrafish *Danio rerio* and nematode *Caenorhabditis elegans*. *Sci. Total Environ.*, 2018, 619, 1-8.
- [9] Weber, A., Scherer, C., Brennholt, N., Reifferscheid, G. and Wagner, M., PET microplastics do not negatively affect the survival, development, metabolism and feeding activity of the freshwater invertebrate *Gammarus pulex*. *Environ. Pollut.*, 2018, 234, 181-189.
- [10] Cera, A., Gallitelli, L., Cesarini, G. and Scalici, M., Occurrence of microplastics in freshwater. In *Microplastic Pollution*, Springer, Cham, 2022, pp. 201-226.
- [11] Shruti, V. C., Pérez-Guevara, F., Elizalde-Martínez, I. and Kutralam-Muniasamy, G., First study of its kind on the microplastic contamination of soft drinks, cold tea and energy drinks-Future research and environmental considerations. *Sci. Total Environ.*, 2020, 726, 138580.
- [12] Semmouri, I., Vercauteren, M., Van Acker, E., Pequeur, E., Asselman, J. and Janssen, C., Presence of microplastics in drinking water from different freshwater sources in Flanders (Belgium), an urbanized region in Europe. *Int. J. Food Contam.*, 2022, 9(1), 1-11.
- [13] Selvam, S., Manisha, A., Venkatramanan, S., Chung, S. Y. and Paramasivam, C. R., Microplastic presence in commercial marine sea salts: A baseline study along Tuticorin Coastal salt pan stations, Gulf of Mannar, South India. *Mar. Pollut. Bull.*, 2020, 150, 110675.
- [14] Ragusa, A., Notarstefano, V., Svelato, A., Belloni, A., Gioacchini, G., Blondeel, C., Zucchelli, E., De Luca, C., D'Avino, S., Gulotta, A., Carnevali, O. and Giorgini, E., Raman Microspectroscopy Detection and Characterisation of Microplastics in Human Breastmilk. *Polym.*, 2022, 14(13), 2700.
- [15] Liu, S., Guo, J., Liu, X., Yang, R., Wang, H., Sun, Y., Chen, B. and Dong, R., Detection of various microplastics in placentas, meconium, infant feces, breastmilk and infant formula: A pilot prospective study. *Sci. Total Environ.*, 2023, 854, 158699.
- [16] Ragusa, A., Svelato, A., Santacroce, C., Catalano, P., Notarstefano, V., Carnevali, O., Papa, F., Rongioletti, M.C.A., Baiocco, F., Draghi, S., D'Amore, E. and Giorgini, E., Plasticenta: First evidence of microplastics in human placenta. *Environ. Int.*, 2021, 146, 106274.
- [17] Sruthy, S. and Ramasamy, E. V., Microplastic pollution in Vembanad Lake, Kerala, India: the first report of microplastics in lake and estuarine sediments in India. *Environ. Pollut.*, 2017, 222, 315-322.
- [18] Srinivasalu, S., Natesan, U., Ayyamperumal, R., Kalam, N., Anbalagan, S., Sujatha, K. and Alagarasan, C., Microplastics as an emerging threat to the freshwater ecosystems of Veeranam lake in south India: a multidimensional approach. *Chemosphere*, 2021, 264, 128502.
- [19] Chandra, R., Nishadh, K. A. and Azeez, P. A., Monitoring water quality of Coimbatore wetlands, Tamil Nadu, India. *Environ. Monit. Assess.*, 2010, 169(1), 671-676.
- [20] Guptha, M. B., Vijayan, L., Sandaliyan, S. and Sridharan, N., Status of Wetlands and Wetland Birds in Coimbatore, Trichy, Perambalare and Thiruvavur Districts in Tamil Nadu, India. *World Journal of Zoology*, 2011, 6(2), 154-158.
- [21] Tien, C. J., Wang, Z. X. and Chen, C. S., Microplastics in water, sediment and fish from the Fengshan River system: Relationship to aquatic factors and accumulation of polycyclic aromatic hydrocarbons by fish. *Environ. Pollut.*, 2020, 265, 114962.
- [22] Afrin, S., Uddin, M. K. and Rahman, M. M., Microplastics contamination in the soil from Urban Landfill site, Dhaka, Bangladesh. *Heliyon*, 2020, 6(11), e05572.
- [23] Masura, J., Baker, J. E., Foster, G. D., Arthur, C. and Herring, C., Laboratory methods for the analysis of microplastics in the marine environment: recommendations for quantifying synthetic particles in waters and sediments. National Oceanic and Atmospheric Administration, U.S. Department of Commerce., 2015.
- [24] Murphy, F., Russell, M., Ewins, C. and Quinn, B., The uptake of macroplastic & microplastic by demersal & pelagic fish in the Northeast Atlantic around Scotland. *Mar. Pollut. Bull.*, 2017, 122(1-2), 353-359.
- [25] Karami, A., Golieskardi, A., Choo, C. K., Romano, N., Ho, Y. B. and Salamatinia, B., A high-performance protocol for extraction of microplastics in fish. *Sci. Total Environ.*, 2017, 578, 485-494.
- [26] Pellini, G., Gomiero, A., Fortibuoni, T., Ferrà, C., Grati, F., Tassetti, A. N. and Scarcella, G., Characterization of microplastic litter in the gastrointestinal tract of *Solea solea* from the Adriatic Sea. *Environ. Pollut.*, 2018, 234, 943-952.
- [27] Kapp, K. J. and Yeatman, E., Microplastic hotspots in the Snake and Lower Columbia rivers: A journey from the Greater Yellowstone Ecosystem to the Pacific Ocean. *Environ. Pollut.*, 2018, 241, 1082-1090.
- [28] Tibbetts, J., Krause, S., Lynch, I. and Sambrook Smith, G. H., Abundance, distribution, and drivers of microplastic contamination in urban river environments. *Water*, 2018, 10(11), 1597.
- [29] Cole, M., Lindeque, P., Halsband, C. and Galloway, T. S., Microplastics as contaminants in the marine environment: a review. *Mar. Pollut. Bull.*, 2011, 62(12), 2588-2597.
- [30] Anderson, J. C., Park, B. J. and Palace, V. P., Microplastics in aquatic environments: implications for Canadian ecosystems. *Environ. Pollut.*, 2016, 218, 269-280.
- [31] Daniel, D. B., Ashraf, P. M. and Thomas, S. N., Microplastics in the edible and inedible tissues of pelagic fishes sold for human consumption in Kerala, India. *Environ. Pollut.*, 2020, 266, 115365.
- [32] Karami, A., Golieskardi, A., Ho, Y. B., Larat, V. and Salamatinia, B., Microplastics in eviscerated flesh and excised organs of dried fish. *Sci. Rep.*, 2017, 7(1), 1-9.
- [33] Abbasi, S., Soltani, N., Keshavarzi, B., Moore, F., Turner, A. and Hassanaghahi, M., Microplastics in different tissues of fish and prawn from the Musa Estuary, Persian Gulf. *Chemosphere*, 2018, 205, 80-87.
- [34] Akhbarizadeh, R., Moore, F. and Keshavarzi, B., Investigating microplastics bioaccumulation and biomagnification in seafood from the Persian Gulf: a threat to human health?. *Food Addit Contam Part A*, 2019, 36(11), 1696-1708.
- [35] Burns, E. E. and Boxall, A. B., Microplastics in the aquatic environment: Evidence for or against adverse impacts and major knowledge gaps. *Environ. Toxicol. Chem.*, 2018, 37(11), 2776-2796.
- [36] Jovanovic, B., Gökdağ, K., Güven, O., Emre, Y., Whitley, E. M. and Kideys, A. E., Virgin microplastics are not causing imminent harm to fish after dietary exposure. *Mar. Pollut. Bull.*, 2018, 130, 123-131.
- [37] Kolandhasamy, P., Su, L., Li, J., Qu, X., Jabeen, K. and Shi, H., Adherence of microplastics to soft tissue of mussels: a novel way to uptake microplastics beyond ingestion. *Sci. Total Environ.*, 2018, 610, 635-640.
- [38] Feng, Z., Zhang, T., Li, Y., He, X., Wang, R., Xu, J. and Gao, G., The accumulation of microplastics in fish from an important fish farm and mariculture area, Haizhou Bay, China. *Sci. Total Environ.*, 2019, 696, 133948.
- [39] Kaiser, N., Sidra, S., Javid, A., Iqbal, A., Amjad, M., Azmat, H., Arooj, F., Farooq, K., Nimra, A. and Ali, Z., Microplastics abundance in abiotic and biotic components along aquatic food chain in two freshwater ecosystems of Pakistan. *Chemosphere*, 2023, 137177.
- [40] Jian, M., Zhang, Y., Yang, W., Zhou, L., Liu, S. and Xu, E. G., Occurrence and distribution of microplastics in China's largest freshwater lake system. *Chemosphere*, 2020, 261, 128186.
- [41] Bilal, M., Qadir, A., Yaqub, A., Hassan, H. U., Irfan, M. and Aslam, M., Microplastics in water, sediments, and fish at Alpine River, originating from the Hindu Kush Mountain, Pakistan: implications for conservation. *Environ. Sci. Pollut. Res.*, 2022, 1-12.
- [42] Hossain, M. J., Aftabuddin, S., Akhter, F., Nusrat, N., Rahaman, A., Sikder, M. N. A., Monwar, M.M., Chowdhury, M.S.N., Jiang, S., Shi, H. and Zhang, J., Surface water, sediment, and biota: The first multi-compartment analysis of microplastics in the Karnafully river, Bangladesh. *Mar. Pollut. Bull.*, 2022, 180, 113820.
- [43] Hossain, S., Siddika, A., Saifullah, A. S. M., Sheikh, S. and Uddin, M. J., Abundance and distribution of microplastics in surface water and sediment of two selected rivers in Bangladesh. *Environ. Eng. Manag. J.*, 2022, 21(6).
- [44] Barboza, L. G. A., Lopes, C., Oliveira, P., Bessa, F., Otero, V., Henriques, B., Raimundo, J., Caetano, M., Vale, C. and Guilhermino, L., Microplastics in wild fish from North East Atlantic Ocean and its potential for causing neurotoxic effects, lipid oxidative damage, and human health risks associated with ingestion exposure. *Sci. Total Environ.*, 2020, 717, 134625.

- [45] El-Naggar, H. A., Allah, H. M. K., Masood, M. F., Shaban, W. M. and Bashar, M. A., Food and feeding habits of some Nile River fish and their relationship to the availability of natural food resources. *Egypt. J. Aquat. Res.*, 2019, 45(3), 273-280.
- [46] Boerger, C. M., Lattin, G. L., Moore, S. L. and Moore, C. J., Plastic ingestion by planktivorous fishes in the North Pacific Central Gyre. *Mar. Pollut. Bull.*, 2010, 60(12), 2275-2278.
- [47] Setälä, O., Lehtiniemi, M., Coppock, R. and Cole, M., Microplastics in marine food webs. In *Microplastic contamination in aquatic environments*, Elsevier, 2018, pp. 339-363.
- [48] Martí, E., Martín, C., Galli, M., Echevarría, F., Duarte, C. M. and Cózar, A., The colors of the ocean plastics. *Environ. Sci. Technol.*, 2020, 54(11), 6594-6601.
- [49] Balogun, J. K., Fish distribution in a small domestic water supply reservoir: A case study of Kangimi Reservoir, Kaduna, Nigeria. 19th Annual Conference of the Fisheries Society of Nigeria (FISON), Ilorin, Nigeria, 2005, 832-837
- [50] Rios, J. M., Tesitore, G. and de Mello, F. T., Does color play a predominant role in the intake of microplastics fragments by freshwater fish: an experimental approach with *Psalidodon eigenmanniorum*. *Environ. Sci. Pollut. Res.*, 2022, 1-8.
- [51] Ferreira, M., Thompson, J., Paris, A., Rohindra, D. and Rico, C., Presence of microplastics in water, sediments and fish species in an urban coastal environment of Fiji, a Pacific small island developing state. *Mar. Pollut. Bull.*, 2020, 153, 110991.
- [52] Food and Drug Administration (FDA), N95 respirators and surgical masks (face masks). Food and Drug Administration. USA, 2020.
- [53] Baka, A., Cenciarelli, O., Kinross, Pete., Plachouras, D., Suetens, C., Tseroni, M. and Weist, K., Use of gloves in healthcare and non-healthcare settings in the context of the COVID-19 pandemic. Technical Report, European Centre for Disease Prevention and Control (ECDC): Stockholm, 2020.
- [54] Haritha, T.N. and Siddhuraju, P., Is the covid-19 pandemic increasing the microplastic load in our environment? *Pollut. Res.*, 2021, 40(3): 817-822.
- [55] Espinosa, C., Esteban, M. Á. and Cuesta, A., Dietary administration of PVC and PE microplastics produces histological damage, oxidative stress and immunoregulation in European sea bass (*Dicentrarchus labrax* L.). *Fish Shellfish Immunol.*, 2019, 95, 574-583.
- [56] Choi, D., Bang, J., Kim, T., Oh, Y., Hwang, Y. and Hong, J., In vitro chemical and physical toxicities of polystyrene micro fragments in human-derived cells. *J. Hazard. Mater.*, 2020, 400, Article 123308.
- [57] D'Angelo, S. and Meccariello, R., Microplastics: a threat for male fertility. *Int. J. Environ. Res. Public Health.*, 2021, 18(5), 2392.
- [58] Horvatits, T., Tamminga, M., Liu, B., Sebode, M., Carambia, A., Fischer, L., Püschel, K., Huber, S. and Fischer, E. K., Microplastics detected in cirrhotic liver tissue. *EBioMedicine.*, 2022, 82, 104147.
- [59] Amato-Lourenço, L. F., Carvalho-Oliveira, R., Júnior, G. R., dos Santos Galvão, L., Ando, R. A. and Mauad, T., Presence of airborne microplastics in human lung tissue. *J. Hazard. Mater.*, 2021, 416, 126124.
- [60] Jenner, L. C., Rotchell, J. M., Bennett, R. T., Cowen, M., Tentzeris, V. and Sadofsky, L. R., Detection of microplastics in human lung tissue using μ FTIR spectroscopy. *Sci. Total Environ.*, 2022, 831, 154907.
- [61] Leslie, H. A., Van Velzen, M. J., Brandsma, S. H., Vethaak, A. D., Garcia-Vallejo, J. J. and Lamoree, M. H., Discovery and quantification of plastic particle pollution in human blood. *Environ. Int.*, 2022, 163, 107199.
- [62] Noda, I., Dowrey, A. E., Haynes, J. L. and Marcott, C., Group frequency assignments for major infrared bands observed in common synthetic polymers. In *Physical properties of polymers handbook*, Springer, New York, 2007, pp. 395-406.
- [63] Chércoles Asensio, R., San Andrés Moya, M., de la Roja, J. M., & Gómez, M. (2009). Analytical characterization of polymers used in conservation and restoration by ATR-FTIR spectroscopy. *Anal. Bioanal. Chem.*, 395(7), 2081-2096.
- [64] Jung, M. R., Horgen, F. D., Orski, S. V., Rodriguez, V., Beers, K. L., Balazs, G. H., Jones, T.T., Work, T.M., Brignac, K.C., Royer, S.J., Hyrenbach, K.D., Jensen, B.A. and Lynch, J. M., Validation of ATR FT-IR to identify polymers of plastic marine debris, including those ingested by marine organisms. *Mar. Pollut. Bull.*, 2018, 127, 704-716.
- [65] Mitchell, G., France, F., Nordon, A., Tang, P. L. and Gibson, L. T., Assessment of historical polymers using attenuated total reflectance-Fourier transform infra-red spectroscopy with principal component analysis. *Herit. Sci.*, 2013, 1(1), 1-10.
- [66] Shashoua, Y., Bradley, S. M. and Daniels, V. D., Degradation of cellulose nitrate adhesive. *Stud Conserv.*, 1992, 37(2), 113-119.
- [67] Chang, S., Analysis of polymer standards by Fourier transform infrared spectroscopy-attenuated total reflectance and pyrolysis gas chromatography/mass spectroscopy and the creation of searchable libraries. *Marshall University Forensic Science Program, Atlanta*, 2012.
- [68] Nishikida, K. and Coates, J., Infrared and Raman analysis of polymers. In *Handbook of plastics analysis*, Taylor and francis, CRC Press, 2003, pp. 198-328.

