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A Preliminary Study on Microplastic Occurrences in Surface Waters of Ousudu Lake, Pondicherry, India.

D. Supriya Varshini [a,*], K. Ramesh [a], K. Srinivasamoorthy [a]

[a] School of Physical, Chemical, and Applied Sciences, Department of Earth Sciences, Pondicherry University, Puducherry-605 014

* Corresponding Author: varshariyas@gmail.com

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Abstract: Microplastics (MP) in both freshwater and marine ecosystem is the next issue that has been recently the fore. However, freshwaters are the potential source and pathway to transport MPs to the marine environment. There is a lack of understanding about the presence and analysis of MP in the freshwater system in India, one of the leading global plastic producers and consumers responsible for 5.6 million tonnes of waste every year. The present attempt is the first in Ousudu Lake, Puducherry, Tamil Nadu, to study the MPs occurrence and examine its properties in the surface water of the largest lake and an important wetland. The concentration range of MP in Ousudu Lake was 0.0039 particles/m^2. Fibre was dominant, homogenous with the size fraction of ≤100µm comprised of total MPs collected in Lake. Raman spectroscopy identified plastics with polyethylene as a homogenous component. This study indicated that the presence of MP in water might influence the environment.

Keywords: Microplastics, Freshwater, Ousudu Lake, Puducherry, Marine Ecosystem

1. Introduction

Microplastics (MP) are solid synthetic organic polymers with particle size <5.0 mm in length that are widespread in the environment. MPs are essentially composed of carbon and hydrogen atoms bonded together as polymer chains [1]. MPs are classified as primary and secondary; the primary include microbeads, plastic pellets, and microfibers from clothing [2]. The secondary MPs are formed from meso or macro-sized plastics that enter the environment undergo physical, biological, and photo-oxidative degradation into micro or nano-sized fragments or even smaller than that are undetectable to naked eyes [2,3]. Some primary sources of secondary MPs include plastic bags, plastic drink bottles, and fishing nets. Both types are found to survive in the environment at peaks, particularly in freshwater and marine ecosystems [4].

There are several uses of MPs. Microbeads are used as exfoliants in personal care products; fibers are used in synthetic clothing and plastic ropes; medical applications as drugs [5]. Further, these microbeads and fibers enter a watershed through wastewater treatment plants [2]. MPs are concentrated in the digestive tracts of some species, including invertebrates, crustaceans, bivalves, and fishes intended for human consumption may cause adverse health complication [6-8]. Inhalation of MPs by humans can cause potential health impacts by particle, biological and chemical toxicities [9]. Recently report on the occurrence of MPs in tap and bottled water is also of growing concern [10]. The sink and source for chemical contaminants are provided by Plastic debris. Abrasion of additives used in plastic manufacturing can enter into the marine environment. On the other hand, hydrophobic contaminants present in the water may adhere to the plastic particles [11]. Thus, MPs may act as a vector to transport concentrated contaminants to organisms [2].

The prevalence and the dispersal of MPs may cause adverse health effects to the marine ecosystem [6]. As the impact of MPs is poorly understood, the demand for understanding it becomes vital [2,3]. The first report on the prevalence of MPs was made along the coasts of New England in 1970 as spherules in plankton tows [10]. Since then, they have been found in most significant water bodies and sediments around the globe. Rivers are isolated as potential sources and pathways to transport MPs to the oceans [12]. Microplastic pollutants (1,000 plastics per liter) were identified in lakes and reservoirs sampled in river Thame and its tributaries by [13]. Even less populated localities like the Falls of Dochart and Loch Lomond in Scotland were isolated with two or three pieces per liter. MPs in bottom-dwelling creatures and sediments from North and the Barents Sea were identified [14,15]. The middle and lower reaches of the Yangtze River and Spain's Mediterranean coast [16] were reported to have high concentrations. Only a few studies of MPs in freshwater ecosystems have been made [2,17-19] although they are increasingly detected in the world (Thompson et al.2004] [20-23].

The first study on MPs attempted in 2011 on MPs in freshwater ecosystems was found to have an average of 37.8 fragments per square meter of Lake Huron sediment samples [24]. Additionally, studies have found MPs with an average concentration of 43,000 MP particle km^2 in Great Lakes [25]. MPs have also been remarkably found in the United States in freshwater ecosystems [24]. The highest concentration of MPs ever discovered was recorded at 4000 particles kg^{-1} in the Rhine River freshwater ecosystem [26]. The first report on Vembanad lake, Kerala, India, emphasized the MPs in the lake and estuarine sediments [27,28]. A few studies of MPs prevalence in lake water samples are still gloomy [29].

Hence the present attempt is in OusuduLake, the largest water body in the Puducherry region. The lake is one of the significant wetlands of Asia that supports a variety of fauna and flora [30,31] The study incorporates field survey and laboratory analysis to evaluate MPs' physical and chemical composition in OsuduLake.

3. Materials and methods

3.1. Study area

Ousudu Lake of 11°56′ - 11°58′ N & 79°44′ - 79°45′ E is a large shallow wetland situated along the eastern boundary of Puducherry with total coverage of 800 ha (Figure.1). It is an inter-state lake situated 10.0 km west of Puducherry town with a water-spread area almost equally shared between Puducherry and Tamilnadu.

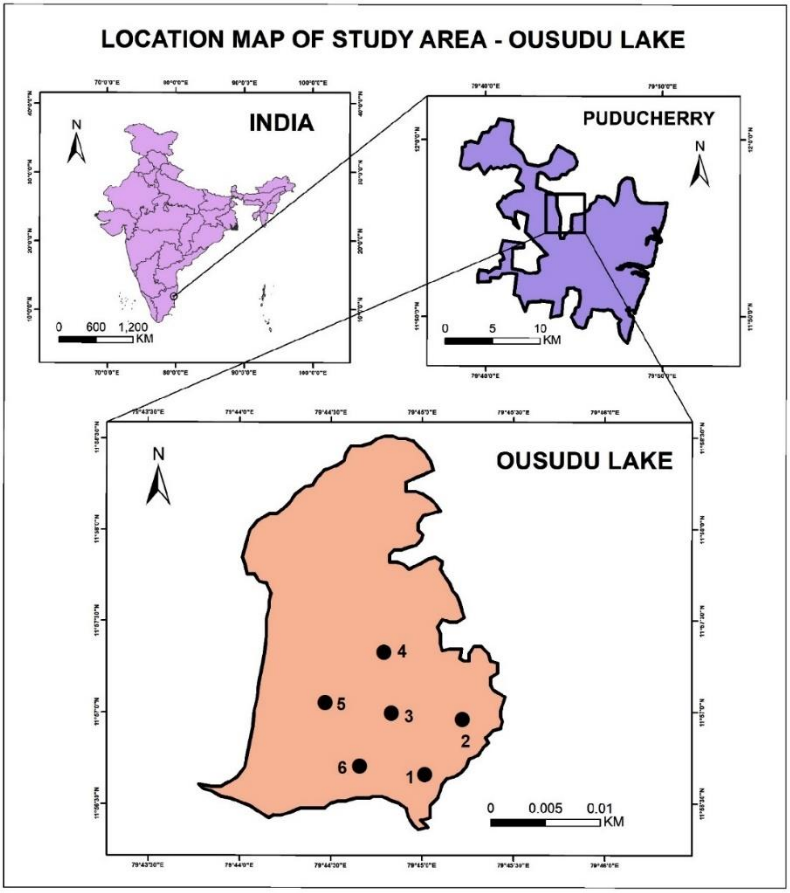

Figure 1. The location map of Ousudu Lake, Pondicherry, Tamil Nadu, India.

The lake is a wetland of national importance by the National Wetland Conservation Programme of the Ministry of Environment and Forests (MoEF), New Delhi [30,31]. The Asian Wetland Bureau declared Ousudu as one of the 115 significant wetlands in Asia and an Important Bird Area (IBA) identified by the BNHS (Bombay Natural History Society). The lake also a livelihood for inhabitants as it provides resources and ecosystem services [32].

Geologically, the lake is underlain by Cuddalore sandstone with overlying alluvium and Manaveli claystone. The lake's catchment is 15.54 km^2 with an average depth of 3.0 meters. The water sources to the lake are mainly from the Suthukeni check dam constructed across the river Sankaraparani. The climate in and around the lake region is humid, with an annual mean temperature between 23.6°C and 33.7°C [32]. The hydrogeological significance of the lake is its capacity to recharge the aquifers. The Vanur-Ramanathapuram sandstone is the principal aquifer that gets recharged, and groundwater from this aquifer is mainly utilized for drinking and irrigation purposes. A total of seven canals with discharge ranges between 0.135 m^3/s and 1.371 m^3/s, mainly used for irrigation utilities (Irfan et al. 2020) [30]. The lake also houses migratory birds and is developed as a tourist spot. Fishing activity is prominent in the lake premises [32].

Sampling techniques

Indigenous manta trawl was fabricated to collect microplastics from the lake environment (Figure.2). For the collection of suspended microplastics, the trawl nets with a mesh size of 300µm have been widely used, especially in marine environments [33]. However, in water, MPs ≤ 300µm can easily escape from the trawl mesh, resulting in a significant miscalculation of MP counts [34]. Therefore, in this study, we employed three layers of 300µm net to collect the samples to detect much smaller plastic particles and minimize error. The dimension of the manta net used is 40 x 70 x 110 cm with a three-layer 300-micron nylon mesh of lightweight and robust 500 ml collector made of PVC material with a mesh window of 100 microns in the apex along with two floating balls attached to either side of the manta net a significant feature that helps manta net to float smoothly in the lake surface.

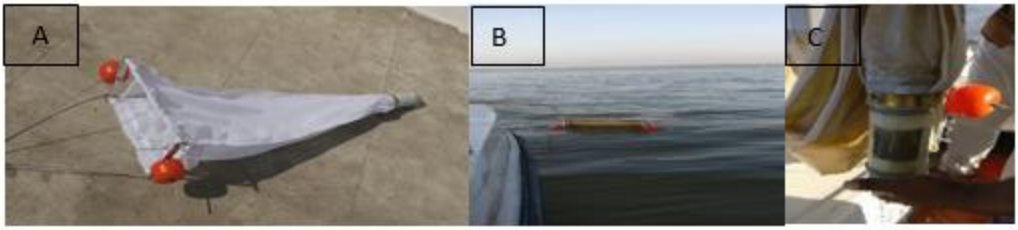

Figure 2. A. Manta net, B. Manta net trawling the surface water, C. Collector

The sampler is also appropriate for collecting inland waters, estuaries, and the open sea under calm conditions. Sampling was attempted in the lake when the wind was calm and with tiny currents after due confirmation with wind and current data from the nearby weather buoy. The sample collection was attempted during February 2019 by collecting the suspended plastic debris in the lake's surface water by trawling the entire volume of water in a zig-zag manner with the help of a motorboat. The speed of the boat while trawling was maintained at 3.0 knots. A total of 6 (Table 1) samplings was attempted, and the plastic debris collected was immediately stored in a rigid plastic 500ml container and immediately shifted to Hydrogeology Laboratory, Department of Earth Sciences, Pondicherry University for further processing.

Table.1 Sampling attempted in the Lake premises

Locations	Coordinates (N)	Coordinates (E)
MPWS – 1	11°56'42"	79°44'38.4"
MPWS – 2	11°56'56.4"	79°45'14.4"
MPWS – 3	11°56'60"	79°44'49.2"
MPWS – 4	11°57'18"	79°44'50.2"
MPWS – 5	11°57'3.6"	79°44'27.6"
MPWS – 6	11°56'38.4"	79°45'00"

The laboratory methods involve filtration of solids present in the water samples through a stack of sieves arranged in the order of 0.355mm and 0.250mm to segregate the solid material of the appropriate sizes. To determine the solid mass in the sample, the sieved material is then dried (90ºC) in the oven until the moisture discharges. The solids extracted were exposed to wet peroxide oxidation (WPO) by adding 30% hydrogen peroxide and a 0.05M Fe(II) solution to dissolve unstable organic matter and collect plastic debris. WPO mixture is subjected to density separation method where the floating plastic debris is separated from denser undissolved organic matter using 0.3mm Whitman filter and carefully sealed with an aluminum foil in a petri dish. (Table 2).

Table 2. Determination of the mass of solids

Sample No.	a=Mass of empty beaker(g)	b=Mass of dried sample(g)	c=Mass of total solids (b-a=c) (g)
1.	180.76	180.79	0.03
2.	141.97	141.99	0.02
3.	198.27	198.31	0.04
4.	146.71	146.74	0.03
5.	146.90	146.92	0.02
6.	143.92	144.22	0.3

The air-dried petri dish containing plastic debris is further taken to the microscopic examination to study the color and texture of MP. The analysis keenly followed the steps mentioned in the National Oceanic and Atmospheric Administration NOAA protocol [35]. The randomly selected 13 out of 42±4 MP samples were analyzed for polymer composition using Raman spectroscopy.

Using the results obtained from Raman Spectroscopy, the chemical composition of samples was determined. This method is appropriate for determining many common plastics, including polypropylene, polyethylene, polyvinyl chloride, and polystyrene. This method helps to operationally define the MPs as any solid material in the appropriate size range that withstands wet peroxide oxidation, floats in a 5.0 M NaCl solution, and under a high-resolution stereomicroscope qualifies positive visual assessment.

4. Data Analysis

Statistical analyses were attempted for samples subjected to Raman spectroscopy, and the samples were plotted using ArcGIS software. With the Raman polymer spectrum library, the spectra obtained for selected polymer items were identified and studied for their chemical compositions.

5. Results and Discussion

The spectra obtained from Raman spectroscopy have been studied and interpreted for their chemical compound. All samples that are analyzed were found to be polyethylene (PE) (Figure 3).

Microfibers were seen dominantly in all the samples with varying colors (black, blue, pink, purple, transparent, and straw yellow). The sample collected from the lake center was found to have higher MPs and found to decreases towards banks (Figure 4)

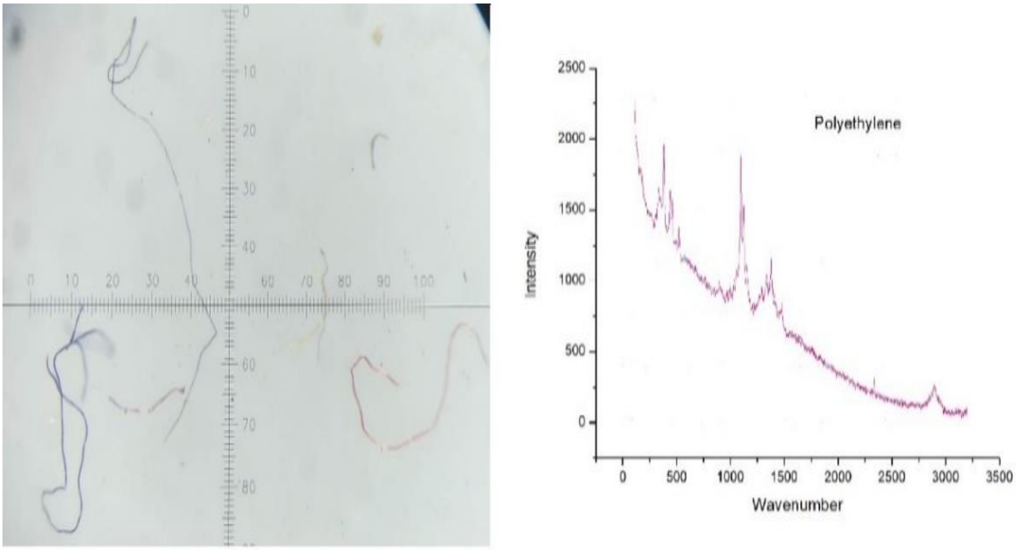

Figure 3 A. MP under a stereomicroscope, B. Spectra of a plastic polymer obtained from Raman

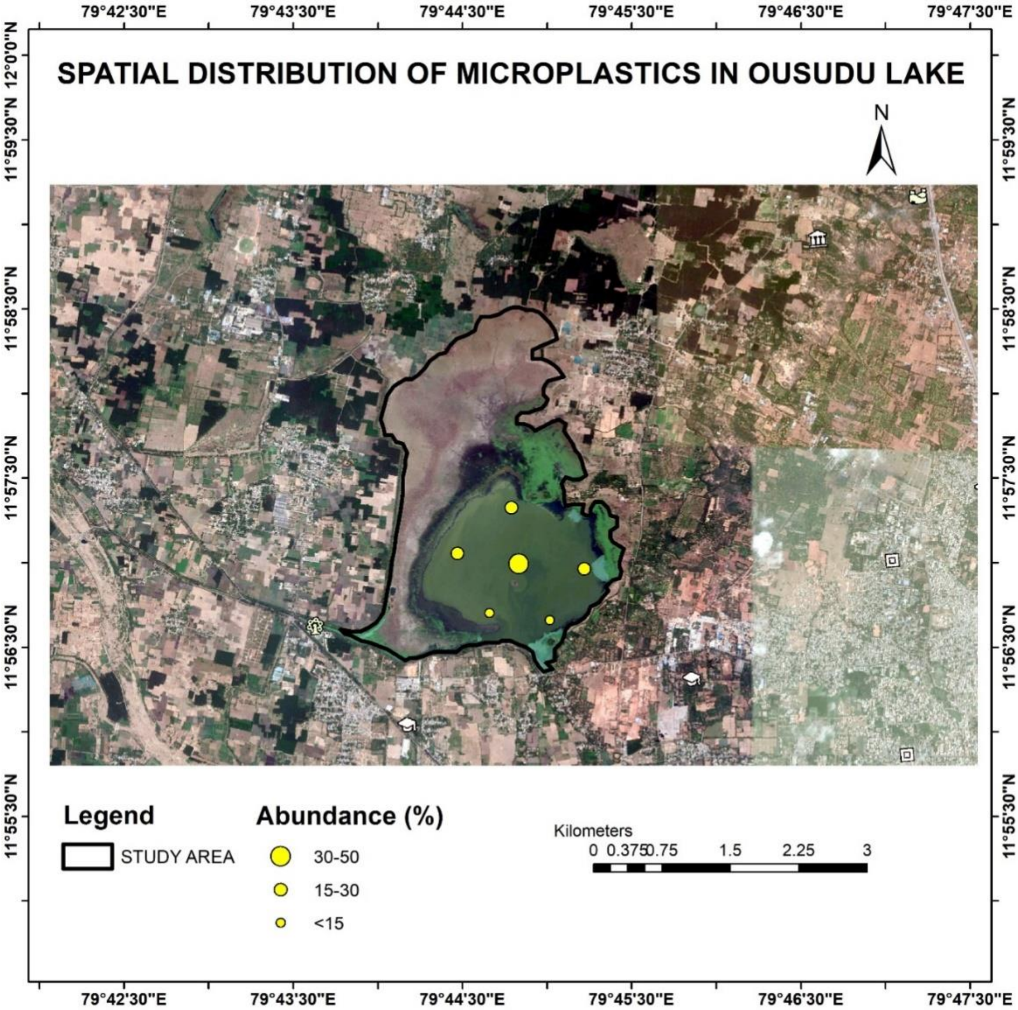

Figure 4. Spatial distributions of MP in the surface water of OusuduLake

5.1 Distribution and abundance of MP in Ousudu Lake

MPs are narrowly distributed with concentration ranges between 7.0 to 35.0 % (Figure 5). Abundances of MPs in the lake manifested uniformity in space. A much higher concentration was detected towards the lake's center, where the depth of water was high, signifying the influences of anthropogenic and fishing activities. An increase in buoyant micro or nano plastic concentration is proportional to the decrease in the water surface, suggesting the cognizance of the relationship between particle size, volume, and surface area [35]. As rural and urban settlements surround the lake, plastic particles present in the effluents from inhabitants and industrial activities might contribute to the lake environment.

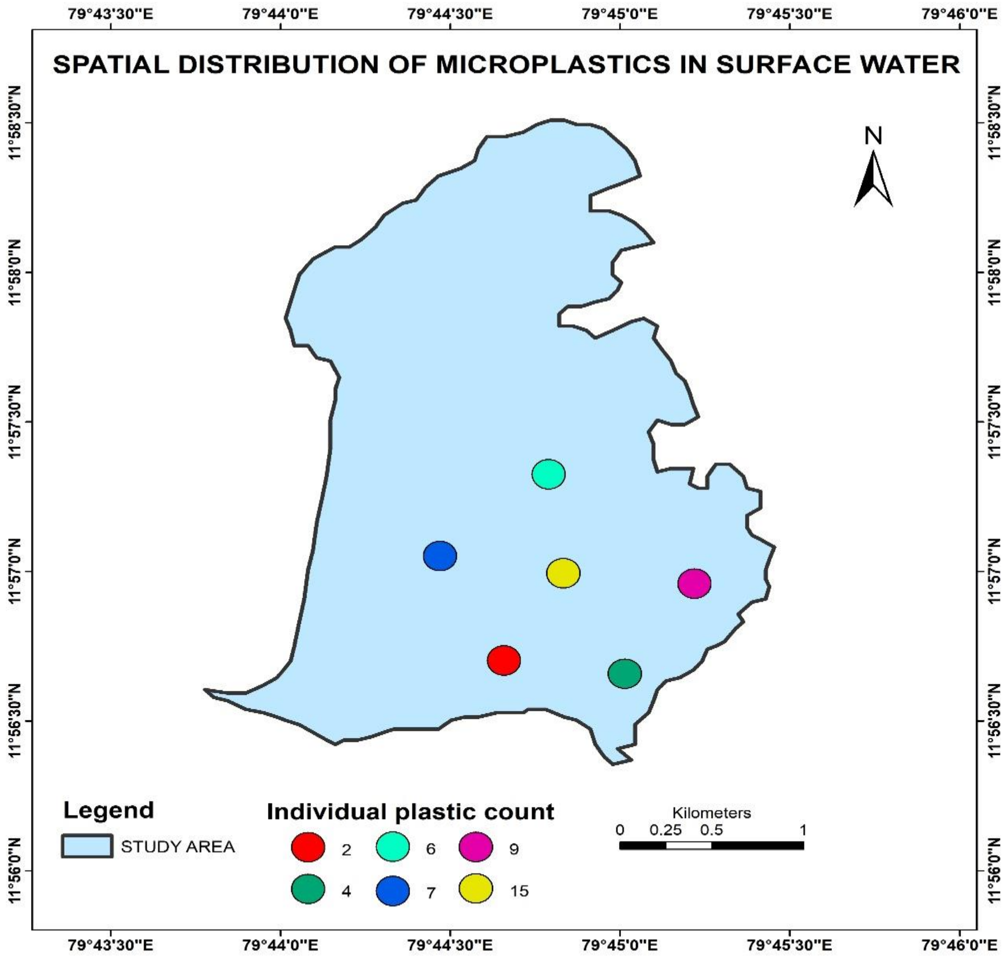

Figure 5. Spatial distribution and abundance of MP in the surface water of Ousudu lake

5.2. Morphology of MPs in Ousudu Lake

A significant part of the breakdown of fishing gears such as nets and ropes from the studied waters might be the reason for the presence of fibrous MPs [36]. Since transparent plastic fibers are widely used in making fishing nets or lines, the oversized proportions of transparent plastic fibers can confirm this hypothesis [37]. Besides, the potential sources of plastic fibers in the water body are surface runoff, atmospheric deposition, agricultural activities, tourists' litter, and domestic and sewage plant effluents [38]. They are likely to have originated due to the fragmentation of plastic bags from the lakeside farms discharged by the watershed inhabitants and tourists or plastic mulch used in irrigation to conserve water and suppress weeds.

MPs exhibited a range of colored particles (Figure 6). Coloration is widely applied to improve the market appeal of plastic goods [39]. The dominance of colored MPs infers that they were most likely to have derived from the breakdown of colored plastic items. Additionally, those with a size of 1.0 mm occupied most MPs with different colors. Additionally, small-sized colored particles of around 1.0 mm majored most MPs, through ingestion can cause particle and chemical toxicities to the visual predators. Although the evidence on plastic ingestion by freshwater organisms is inadequate, in many marine animals, such as birds, fishes, and turtles, colored plastics have been widely detected [40]. Transparent MPs occupied 9.0%, making the least number of total MPs in the lake area, whereas straw yellow and purple were the dominant types.

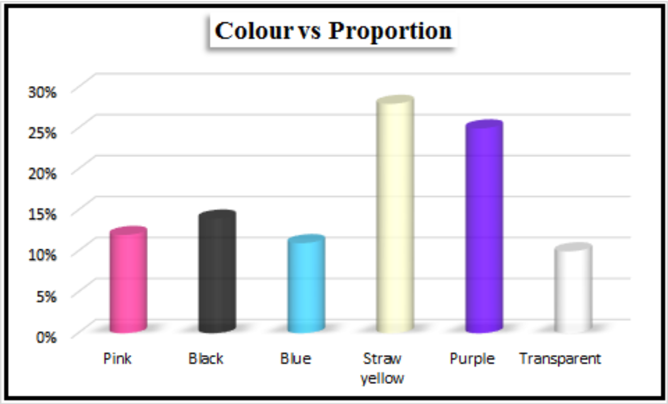

Figure 6. Bar graph showing the color vs. the proportion of MP in the surface water of Ousudu lake.

Randomly selected 13 items were identified using the Raman spectroscopy. From the 13 items analyzed, about seven were confirmed to be plastics. From the components, polyethylene (PE) was the dominant plastic type identified. In order to trace the plastic debris source, identification can provide additional information [41]. The significant global production is predominant and wide use of PE such as plastic bags, bottles, caps, films, and containers in modern life. Therefore, the breakdown of larger plastic debris is possibly attributed to PE particles [42]. In this instance, the untamed fishing activities in Ousudu Lake might be a significant reason for PE as they are essentially the main constituents of fishing lines and nets. PE items are usually buoyant; they can be easily carried and transported by the water due to the lower densities, augmenting the wide distribution [43].

Comparative study

An attempt has been made to compare MPs abundance from the present study with global occurrences (Table 3). The abundance (0.0039 particles/m^2) was in a lower range than other lake areas due to variation in net sizes and comparable with study attempted in Lake Erie by Eriksen et al. 2013.

Table 3. Comparison of MP abundance in surface water of selected freshwater lakes around the world with the present study.

Studied area	Collection	Collection cut-off Size (µm)	Abundance (particles/m2)	Main type recovered	Reference
Lake Erie (range)	Manta net	333	0.0004-4.667	Fragments	Eriksen et al. 2013
Lake Geneva (mean ±SD)	Manta net	300	0.22±0.16	Fragments	Faure et al.2015
Lake Maggiore (mean±SD)	Manta net	300	0.22±0.150	Fiber	Faure et al.2015
Lake Naivasha (range)	Plankton net	150	0.23-0.7	Fiber (81%)	
Lake Taihu (range)	Plankton net	333	0.01-6.8	Fiber (70%)	Su et al. 2016
Three Gorges Dam, China (mean)	Plankton net	112	8.47	-	Zhang et al. 2015
Lake Ousudu	Manta net	300	0.0039	Fiber	Present Study

6. Conclusion

An attempt has been made to characterize the abundance, concentration, and morphology of suspended MPs in the surface waters of Ousudu Lake. MPs were dominant with fiber types of colors ranging from black, pink, purple, transparent, and straw yellow. The spatial distribution suggests microplastic dominance at the lake center and is found to decrease in the banks. Microplastics concentration ranges observed were between 7.0 to 35.0 %. Samples subjected to Raman spectroscopy confirmed polyethylene as the dominant plastic-type suggesting possible sources from larger plastic debris. Global comparison of microplastic with the present study suggests variation in net sizes influencing abundance.

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