

RESEARCH ARTICLE

CHARACTERIZATION OF MICRO-PLASTICS IN WATER AND SEDIMENTS IN BATTICALOA LAGOON AT KATTANKUDY

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ABSTRACT

Micro-plastics (mps) are a globally ubiquitous contaminant and the occurrence and accumulation of mps in the aquatic environment is nowadays an undeniable fact. The present study intends to address morphological characterization and quantification of micro-plastics at Batticaloa lagoon near Kattankudy municipal dumping sites during the period of September 2019 to February 2020. A one-liter backet and Ekman grab sampler were utilized to collect water samples and sediments, respectively. Density separation was carried out using Nacl solution and all floating solids were subject to a wet per-oxidation method and observed under a stereomicroscope. All the recovered micro-plastics were sorted into categories based on the size (1 mm, 1-2 mm, 2-4 mm) shapes (film, fragment, filament, foam, pellet, microbeads) and colour (white, black, transparent and other colours). Kattankudy sample stations showed mps of 1638.83 ±71.69 items kg^{-1} in sediment and 1028.33 ± 73.73 items per liter in surface water. Lagoon-shore sample site showed highest number of mps (surface water 691.10 ±28.50 items per liter, sediments 1033.00 ±28.80 items kg^{-1}) than lagoon sample sites. Overall abundance of mps was statistically significant ($p<0.05$; one-way Anova) among the study sites. Fragments were the most abundant particle shapes found within the sediments (~33%) and a greater number of films were overwhelmed in surface water (~47%) from both study sites. Less than 1 mm size fraction was the most common in sediments while somewhat larger sizes 2-4 mm was dominant in surface water. An assortment of colors was found in the mps gathered from both surface water and sediment among that in shore ~51% white colour and inside the lagoon ~27% were transparent. This study indicates evidence of micro-plastics pollution present in Kattankudy stations, which calls urgent precautionary measures to mitigate mps pollution. Further research is expected to address real impacts of these micro-contaminants on the lagoon environment in future.

Keywords: *Lagoon, Micro-plastics, Sediment, Surface water*

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1. INTRODUCTION

Plastics are a wide range of synthetic or semi synthetic materials that use polymers as a main ingredient. The diversity of polymers and the versatility of their properties including lightweight, strong, durable, corrosion-resistant materials, with high thermal and electrical insulation properties are used to make a vast array of products. The global plastic market is projected to grow from $457.73 billion in 2022 to $643.37 billion by 2029, at a CAGR of 5.0% in forecast period 2022-2029. The proliferation of plastics use, in combination with poor end-of-life waste management, has resulted in widespread, persistent plastics pollution. Only 9% of plastic wastes were recycled, and 12% incinerated, leaving nearly 80% to accumulate in landfills or the natural environment [1].

Plastics are not easily degraded in the environment due to their stable physicochemical structures [2, 3]. However, they are broken down into smaller pieces with time in the presence of heat of the sun, light, oxygen and microbes. These smaller pieces which were less than 5mm in size are known as secondary micro-plastics.

The proliferation of plastics use, in combination with poor end-of-life waste management, has resulted in widespread, persistent micro-plastics pollution [4, 5]. Most of plastic waste is disposed in landfills and a huge amount of plastic waste still appears in the environment due to mismanagement of waste. These tiny particles are carried out by surface runoff and wind and finally it can reach water bodies along with rivers, lakes, and ocean [6] lead to increased contamination in aquatic environments. They have been reported to be ubiquitously present in water, sediments and animals at varying level [7]. They are often mistaken as food and ingested by aquatic animals of all sizes and through this food chain finally, it reaches humans.

These miniature particles are really a big issue as it made up of dangerous chemicals on their own. Plastics can actually leak this chemical in the environment and also act like a magnet and they attract all other toxic chemicals like pesticides in the environment forming very dangerous cocktail for all kinds of organisms. Ingestion of tiny plastics in aquatic organisms can lead wounds, impairments of feeding capacity, blockage of digestive tract followed by satiation and starvation, and general debilitation often leading death. In human this toxic chemical typically acts as an endocrine disturber [8] and these chemicals on their own known to cause cancer, diabetes, heart disease, decrease fertility etc. [9].

The present and distribution of micro-plastics, have been studied in detail in marine ecosystems in Sri Lanka. However, such studies are limited in lagoon ecosystems in the country. Therefore, to fill this knowledge gap, the present study was carried out to investigate micro-plastics in lagoon sediments and surface water in Kattankudy lagoon area in Batticaloa district in Sri Lanka.

2. MATERIAL AND METHODS

2.1 Sampling locations and study period

Twelve sampling locations were selected considering the distance from lagoon shore. The GPS coordinates and survey map for the selected locations are given in Table 1 and Figure 1 respectively. The sampling event of the study was performed from September 2019 to February 2020.

Table 1: Location of the sample sites

Kattankudy Sample Station		
	Kattankudy (K)	Geographical Coordinates
Lagoon -shore (SH)	K-SH-0(SH-1 starting point)	7.675749º N,81.725922º E
	K-SH-1	7.675387º N,81.725967º E
	K-SH-2	7.675124º N,81.726211º E
	K-SH-3	7.674933º N,81.726518º E
	K-SH-4	7.674572º N,81.726518º E
	K-SH-5	7.674247º N,81.726363º E
From shore to 10 m in the lagoon (SP)	K-SP-0(SP-1 starting point)	7.675749º N,81.725831º E
	K-SP-1	7.675387º N,81.725876º E
	K-SP-2	7.675034º N,81.726183º E
	K-SP-3	7.674861º N,81.726464º E
	K-SP-4	7.674590º N,81.726427º E
	K-SP-5	7.674283º N,81.726245º E
From shore to 20 m in the lagoon (SQ)	K-SQ-0(SQ-1 starting point)	7.675749º N,81.725741º E
	K-SQ-1	7.675406º N,81.725785º E
	K-SQ-2	7.674943º N,81.726156º E
	K-SQ-3	7.674789º N,81.726391º E
	K-SQ-4	7.674617º N,81.726346º E
	K-SQ-5	7.674319º N,81.726136º E

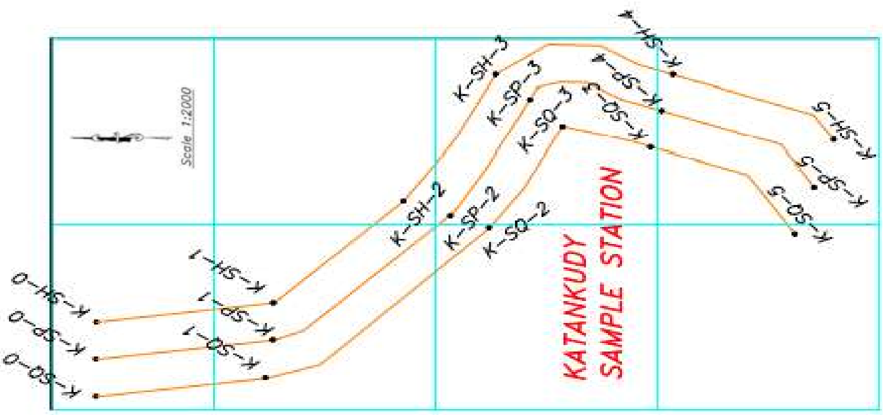

Figure 1: Survey map

2.2 Sampling

Sampling was carried out within 200 m area as shown in Figure 2. Both lagoon-shore and lagoon sample sites were divided into five study sites perpendicularly from shore towards the lagoon thus, each study sites covered 40 m and named as SH1 - SH5, SP1-SP5, SQ1-SQ5 in lagoon-shore, shore to 10 m, shore to 20 m respectively. For each study site, surface water and sediment samples were collected as described by previous study reports with little modifications [10]. Duplicate samples were collected carried out at each study site [10]. All the sampling locations were in the vicinity of garbage disposal area in Kattankudy.

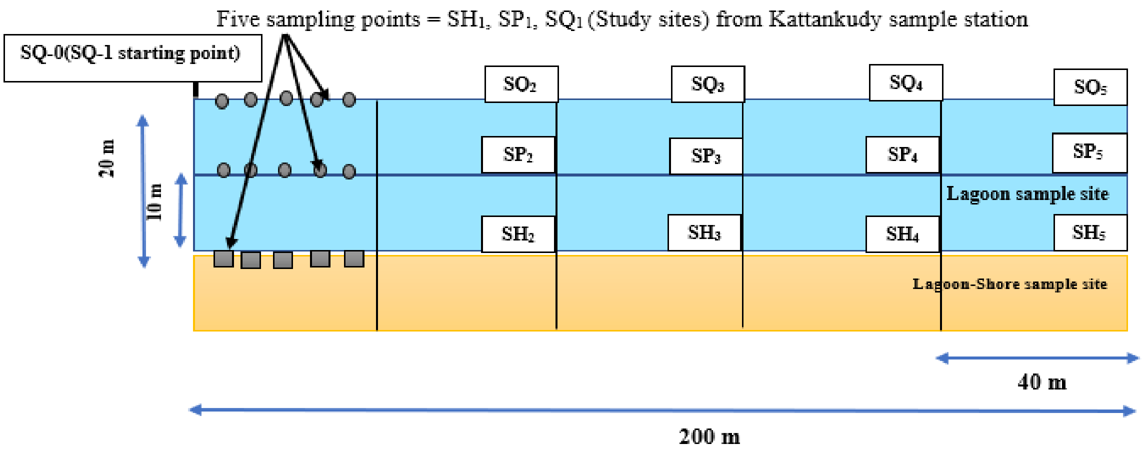

Figure 2: Diagrammatic representation of sample collection

2.2.1 Collection of sediments

In lagoon-shore sample sites, five quadrates (0.5 m x 0.5 m) were selected randomly for each study site (total number of quadrates = 25). All surface sediments (2-5 cm depth) in each quadrate were collected with a metallic shovel and they were mixed together to make a single composite sample for each study site (SH) [10].

Similarly, sediment collection was done in lagoon sample sites. But instead of metal shovel. Ekman grab sampler was used due to the presence of water in the lagoon. The collected samples were named as SP1-S to SP5-S and SQ1-S to SQ5-S from shore to 10 m and 20 m respectively [11, 12].

2.2.2. Collection of water sample

One-liter surface water sample was collected (prior to the sediment collection) at same sediment collection points (SH, SP, SQ) and mixed together to produce a single composite sample for each study site. Then collected water was filtered with 0.25 mm and 4 mm stainless sieves. All of the small solids in the sieves were rinsed carefully into a 1 L glass jar with distilled water while bulk samples were discarded.

All the collected samples were placed in the sample box to avoid shaking and contamination during transportation. The sample box was transported to the laboratory of the Department of Zoology, Eastern University, Sri Lanka for analysis as early as possible.

2.3 Laboratory analysis

Each sample was processed using a stepwise approach include sieving, wet peroxide method, density separation to separate micro-plastics from sediments and surface water samples.

2.3.1 Sieving

Each sample was sieved by using a stack arrangement of stainless-steel mesh sieves which were 4 mm (5mesh) and 0.25mm (60mesh). Retaining sample on 4mm sieves were discarded. All solids collected in the 0.25mm sieve were transfer into the 500ml beaker. Then each beaker was kept an oven at 90ºC for 24 hours for sample dryness.

2.3.2 Wet peroxide oxidation (WPO)

The main aim to perform this was to reduce the organic matter presents in the sample. To perform the WPO test 20ml of aq. 0.05 M Fe (II), 20ml of hydrogen peroxide were added to the 500ml solid sample beaker. To increase the density of solution, 6g of NaCl was added.

2.3.3 *Density separation*

A simple density separator has been used as per the procedures explained by Masura et al., 2015 [13]. Saturated NaCl solution (density 1.20gcm^{-3}) was used for extract micro-plastics from samples.

2.3.4 Hot Needle Test

This test was useful in case of difficult to distinguish between plastic pieces and organic matter. The end of a needle was heated under the flame of a lighter until it glows. The micro-plastics samples were touched by the end of the hot needle, ideally under a microscope. In the presence of a very hot needle, plastic pieces are melted or curled. Biological and other non-plastic materials are not melted or clued [14].

2.4 Observation and Identification of Micro-plastics

Each of the treated Micro-plastics from water and sediment samples was placed in a pre-cleaned Petri dish for observation. The Petri dishes were placed under a stereomicroscope with magnification 10X for examination and photos were captured by using 8 mega pixels camera. Finally, suspected particles were identified according to their morphological characteristics. The identification was based on classification standards from previous studies [15]. The quantity, size, color and shape of the micro-plastics were recorded. Abundances were recorded as items/L in surface water and items kg^{-1} dry sediment. Micro-plastics size determination was performed using the sieve cascade with mesh sizes 1mm, 2mm, and 4mm.

2.5 Quality Assurance and Quality Control

A series of measures were adopted to avoid potential background contamination during sampling and laboratory processing of samples. All containers and experimental instruments were pre-cleaned three times by distilled water and wrapped in aluminum foil when not in use to avoid air bone contamination.

2.6 Statistical analysis

One-way ANOVA was carried out using Minitab 19 software program to assess the statistical significance of abundance levels among the study sites in both sample stations. Correlation analysis was carried between the Micro-plastics abundance and the sample sites, in between the size fractions of micro-plastics by Pearson correlation. Here all statistical analysis was checked at 0.05% significant level. The graph which relevant to analysis were plotted by using of Microsoft Excel 2019 software.

3. RESULTS

3.1 Abundance of micro-plastics

Micro-plastics were evident at all study sites of Kattankudy sample stations. The perceived total Micro-plastics abundance respect to sample sites in sediment and surface water are presented in Table 2 . The abundance levels of micro-plastics among study sites were statistically significant (P<0.05; One-way ANOVA).

Table 2: Total mean (Average ± standard deviation) and range of micro-plastics abundance

Sample Sites	Sample Type	Unit	Mean Abundance	Range of Abundance
Lagoon –shore (SH)	Surface water	MPs/L	691.10 ± 28.50	658.0-729.0
	Sediment samples	MPs/Kg dry weight	1033.00 ± 28.80	995.5-1068.0
From shore to 10m in the lagoon (SP)	Surface water	MPs/L	251. 20 ± 32.30	219.5-296.0
	Sediment samples	MPs/Kg dry weight	423.10 ± 29.80	380.0-454.5
From shore to 20m in the lagoon (SQ)	Surface water	MPs/L	86.08 ± 15.52	66.5-111.5
	Sediment samples	MPs/Kg dry weight	182.75 ± 15.71	162.0-199.5

3.1.1 Analysis of micro-plastics from lagoon shore sites

Lagoon-shore sediment analysis: Individual mean abundance of micro-plastics towards the study sites from SH_1-S to SH_5-S consisted of 198.25±11.22 items/Kg dry-weight, 183.58±16.05 items/Kg dry-weight,201.25±4.99 items/Kg dry weight, 213.67±11.16 items/Kg dry-weight and 236.25±8.27 items/Kg dry-weight, respectively. Individual mean abundance of micro-plastics was ranged in between 17% to 22% among the whole study sites. The micro-plastics abundance was statistically significant among study sites (p=0.000, ANOVA).

Lagoon-shore surface water analysis: Individual mean abundance of micro-plastics from SH_1-W to SH_5-W consisted of 137.50±19.08 items/L,118.25±20.54 items/L,140.33±8.55 items/L,147.50±9.73 items/L and 147.50±7.06 items/L respectively. Therefore, the individual mean abundance of micro-plastics was ranged in between 17% and 21% among the whole study sites, as in the sediment sample. Here also the abundance of micro-plastics was statically significant among the study sites (p=0.009, ANOVA).

3.1.2 Comparison of micro-plastics among sample sites

The distribution of micro-plastics varied greatly among lagoon-shore, from shore to 10 m and 20 m in the lagoon. The level of micro-plastics from lagoon- shore to lagoon sample sites were in the order of (SH>SP>SQ).

In Kattankudy sample station, strong correlations of Micro-plastics abundances between lagoon-shore and from shore to 20 m were evident in sediment and surface water and they were statistically significant (Pearson's correlation of sediment = 0.725, p =0.000, and in surface water, Pearson's correlation = 0.547, p = 0.002).

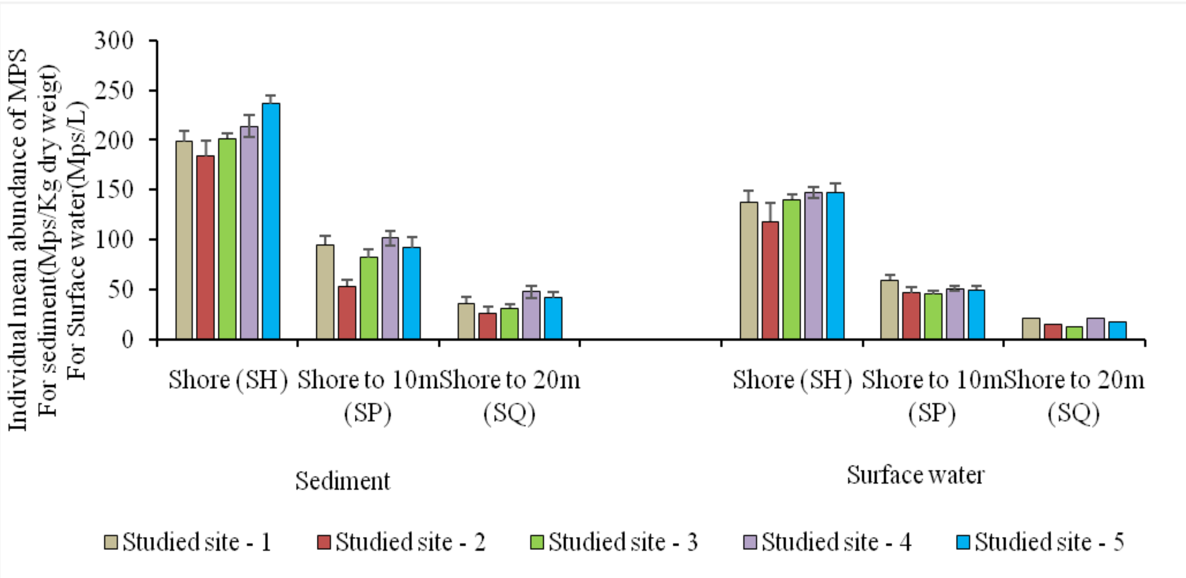

Figure 3: Comparison of micro-plastics among sample sites

3.1.3. Comparison of micro-plastics between sediment and surface water

Approximately 61% of micro-plastics observed from sediment samples and 39% of micro-plastics observed from surface water samples as shown in Figure 4.

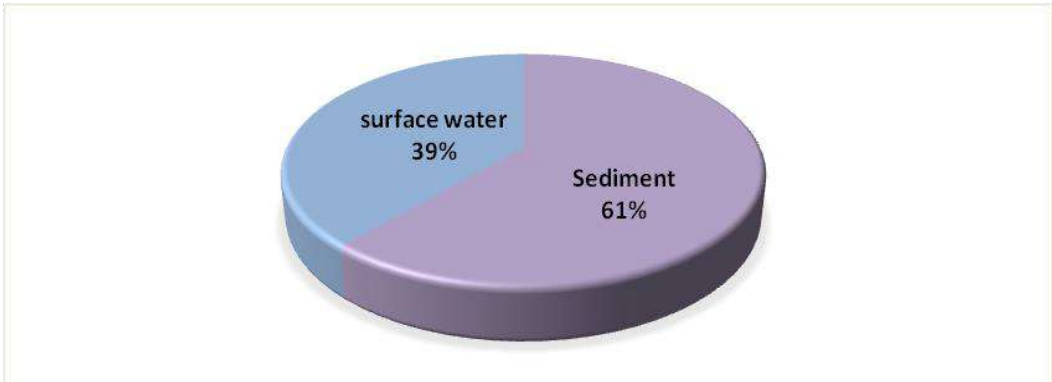

Figure 4: Comparison of micro-plastics between sediment and surface water

3.2 Shape of micro-plastics with abundance

All types of primary and secondary Micro-plastics were found in all sampling stations. The morphological characteristics of the observed micro-plastics are summarized in Figure 5.

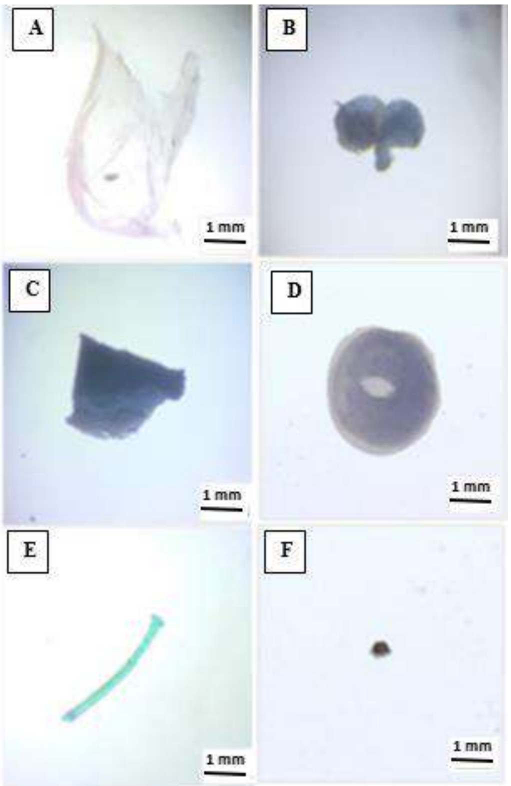

Figure 5: Different shapes of micro-plastics magnified into 10 times: Films (A); Foams (B); Fragments (C); Pellets (D); Filament (E); Microbeads (F).

3.2.1 Comparison of micro-plastic shapes between sediment and surface water

Fragments were higher in sediment than surface water. Films were found more in surface water than sediment samples. Filaments were more common in surface water and sediments. Similarly, foams did not show much difference between surface water and sediments. The level of microbeads was felt to be low. The pellets forms were recorded only in the sediment samples (Figure 6).

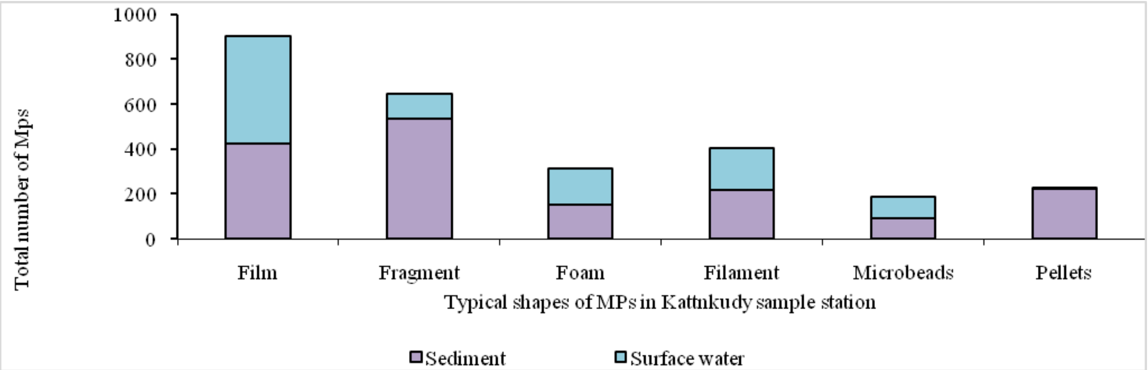

Figure 6: Comparison of Micro-plastics shapes in sediment and surface water

3.3 Colour of micro-plastics

A variety of colors were found in the micro-plastics collected from both surface water and sediments. White micro-plastics were found in large quantities from both lagoon-shore sediment and surface water. Followed by black colour micro-plastics. However, more white and transparent color was observed in lagoon sample sites.

3.4 Size of micro-plastics

At each study site, three small size categories (<1 mm, 1-2 mm, 2-4 mm) were recorded. Size of micro-plastics varied between sediment and surface water (Figure 7). A tendency toward larger Micro-plastics quantities in smaller mesh sizes observed in sediment sample. The number of micro-plastics in surface water samples increased with increasing mesh size.

The Pearson's correlation analysis between the size fractions were clearly noted in Table 3. Quantity of micro-plastics was almost strongly correlated and statistically significant in between the different size fractions of Micro-plastics.

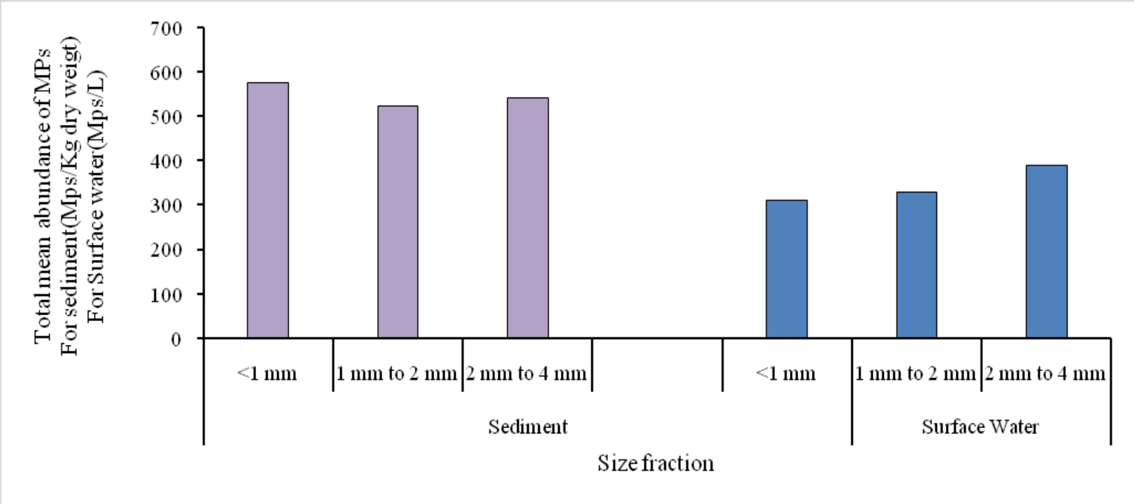

Figure 7: Size fraction comparison between sediment and surface water

Table 3: The Pearson's correlation analysis between the size fractions

Size fraction	Sample type	Pearson's correlation	P value
<l mm and 1mm to 2 mm	Surface water	0.877	0.022
	Sediment	0.904	0.013
<l mm and 2 mm to 4mm	Surface water	0.744	0.090
	Sediment	0.626	0.184
lmm to 2mm and 2mm to 4mm	Surface water	0.935	0.006
	Sediment	0.790	0.062

4. DISCUSSION

4.1 Micro-plastics distribution and pollution level

The highest abundance of micro-plastics was found in lagoon-shore sites compared with lagoon sample sits (Figure 3). A large proportion of human population inhabits near coastal areas [16] and many of them living around the lagoon depend on fishing for their livelihood [18, 19]. Therefore, heavy human pressure could lead to release of plastic litters in this environment [10, 20]. The above deleterious activities could be the key contributor of Micro-plastics contamination in the study area. This further leads to the scenic beauty and health of Kattankudy lagoon-shore sites. Inside the lagoon may be the Hydrodynamic conditions (wind, water current, tidal actions) influence this distribution pattern [10, 17].

On the other hand, wave action and water currents were very low in lagoon environment, thus the breakdown of micro-plastics also in low range therefore most of the plastic particles trapped into the sediment and degrade to forming micro-plastics in sediment than float in to the surface water [17]. Therefore, higher numbers of micro-plastics were observed in sediment samples than surface water samples.

4.2 Shape of micro-plastics and their sources

The municipal dumping activities in lagoon-shore areas were the main source for the high abundance of fragments and films (Figure 6). Large quantities of micro-plastics are produced by disposable packaging which were used to express delivery and takeout food, both have boomed in recent years. Therefore, the dumping sites consist of a greater number of disposable packaging. These plastics were easily broken into the plastic fragments or films. This is could be the reason for the presence of a greater number of films and fragments in lagoon [10, 21]. Considerable number of pellets also present due to dumping actions. In addition, some of the filaments and foams were found in the samples because of the broken fishing nets and regiform boxes that were used for storing fish [10, 12]. The presence of concentric household wastages and poor drainage system may bring a considerable level of microbeads in lagoon [10].

More fragments were found to be denser than water therefore, they sink to the bottom. However, less dense fragments floated in the surface water [16, 22]. Films that are less dense than water easily float in surface water. However, some films were somewhat denser. They were found to be entangled in the sediment. Due to this significant number of films were found in the sediments. However, films had the ability to move easily in water; thus, their spread was more visible in the water column [22].

Filaments are also more likely to float in water. As they are normally less dense, they were found significantly in sediments. Few authors [23] have also found plastic filaments to be the most common type of Micro-plastics present in sediment samples. The filaments are preferentially removed from suspension as they are trapped between settling sand grains. Due to the elongated size of the filaments and the very large ratio of surface area to volume, it is more likely to impacted and dragged downward [24]. Foam usages were observed to some extent due to the significant amount of fishing practices. Similarly, like filaments the diffusion of foam did not show much difference in surface water and sediment. It also relies on low density. But, some foam presented in sediments may be due to accidently burying in sediments.

The pellets forms were recorded only in the sediment samples. Because the pellets were found to be denser than water and thus unable to float in surface water [16, 22]. The level of microbeads was found to be low. This may be attributed to their high solubility in water or stay in water for a short period of time. In addition, they cannot be realized due to small size.

4.3 Colour of micro-plastics

The disappearance of the true color of the plastic in the lagoon-shore may be due to the longer exposure time to sunlight which can cause the natural degradation of Micro-plastics by its ultraviolet radiation. Therefore, most of the time the colour appears white [25]. But in some cases, due to high contamination turn micro-plastics into black or dull colour.

In the lagoon, many transparent plastics are due to the commonly used fishing nets and lines and white colour regiform boxes [26]. Transparent micro-plastics in sediment samples may be attributed to the bleaching caused by digestion [16].

4.4 Size of micro-plastics

A tendency toward larger Micro-plastics quantities in smaller mesh sizes observed in sediment sample. This result was consistence with previous studied reports [12, 27]. A main cause for the prevalence of smaller micro-plastics is the fragmentation of larger plastics presented in the estuarine environment. Larger plastics litters are rapidly started to degrade into smaller fragments, as a result of physical variables (salinity, light, temperature, and humidity) and microbiological degradation [28]. Thus, a large plastic fragment can produce hundreds or thousands of micro-plastics in the lagoon environment.

Moreover, sediments with the highest proportion of finer fraction micro-plastics tend to be more cohesive and flocculate regularly. That’s why micro-plastics may be retained in sediment during flocculation of the particles [27], which are likely to affect the suspension and deposition behavior of micro-plastics [24]. The number of micro-plastics in surface water samples increased with increasing mesh size. This conclusion is consistent with previous studies. A possible explanation is that large plastics are prone to forces of flow and wind leading to floating on water, while smaller plastics tend to migrate into sediments and deep water [16].

CONCLUSION

There was a notable difference in Kattankudy sample station due to the total Micro-plastics abundance level, Micro-plastics distribution across different sediment fractions, and the proportions of different types and colour of micro-plastics. Approximately 61% of micro-plastics observed from sediment samples and 39% of micro-plastics observed from surface water samples. The significant abundance of micro-plastic leads to loss of scenic beauty and health of this lagoon. Without proper future precautions these ubiquitous contaminants become a vital force and destroy the environment.

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