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A Study on Microplastics in Two Different Municipal Dumping Sites of Batticaloa Lagoon: Extraction, enumeration and Characterization

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Abstract: *Microplastics (MPs) are globally ubiquitous contaminants, and the occurrence and accumulation of microplastics in aquatic environments is an undeniable fact. To date, our understanding of microplastics pollution is limited. Therefore, this study intends to address the morphological characterization and quantification of microplastics at the Eravur and Kattankudy municipal dumping sites of Batticaloa Lagoon from September 2019 to February 2020. Normal one-litter backets and Ekman grab samplers were used to collect water samples and sediments, respectively. Density separation was carried out using a NaCl solution, and all floating solids were subjected to a wet peroxidation method and observed under a stereomicroscope. All recovered microplastics were sorted into categories based on their size (1 mm, 1–2 mm, 2–4 mm), shape (film, fragment, filament, foam, pellet, microbeads), and color (White, Black, transparent, and other colors). Kattanludy sample stations generally have great abundance when it compares with Eravur sample station and it consists 1638.83 ±71.69 items kg− 1 in sediment and 1028.33 ± 73.73 items per litre in surface water. The overall abundance of microplastics was statistically significant($p<0.05$) among the sampling stations. Fragment types were the most abundant particle shapes found within the sediments (~33%), and a greater number of film types were overwhelmed in surface water (~44%) from both study sites. The less than 1 mm size fraction was the most common in sediments, while somewhat larger sizes (2–4 mm) were dominant in surface water. An assortment of colors was found in the MPs gathered from both surface water and sediment, with ~51% white color in the shore and ~72% transparent color inside the lagoon. Overall, this study offers evidence of microplastic pollution at both sample stations by municipal dumping and anthropogenic activities. Precautionary measures are urgently required to mitigate this pollution. Further research is expected to address the real impacts of these microcontaminants on the lagoon environment.*

Key words: *Lagoon, Microplastics, Sediment, Surface water*

1. INTRODUCTION

Plastic is a single element in our day-to-day lives. Their use as a part of our everyday routines due to their physical and chemical properties provides durability, lightness, and longevity, coupled with low prime cost. Around 6 300 million tons of plastics waste are thought to have been generated between 1950 and 2015, of which only 9% were recycled, and 12% incinerated, leaving nearly 80% to accumulate in landfills or the natural environment [1]. Plastics may not decompose in the environment for tens to hundreds of years owing to their stable physical and chemical structures [2]. All of this plastic over time with the heat of the sun, light, oxygen, and microbes will break down into smaller pieces, which are known as secondary microplastics. mm, which is less than 5 mm in size. Microplastics can also be made up primarily of small sizes in cosmetics and personal care products [3].

The proliferation of plastic use, in combination with poor end-of-life waste management, has resulted in widespread and persistent microplastic pollution [4,5]. Most plastic waste is disposed to landfills, and a large amount of it appears in the environment due to the mismanagement of plastic waste and its particles carried out by runoff wind. Finally, it can reach water bodies along with rivers, lakes, and

oceans [6], leading to increased contamination in aquatic environments. They have been reported to be ubiquitously present in water, sediment and animals at varying level [7,8,9]. They are often mistaken as food and ingested by aquatic animals of all sizes from tiny plankton to huge whale and also from this food chain finally, it reaches us.

These miniature rubbishes are really a big issue as it made up of dangerous chemicals on their own. Plastics can leak this chemical in the environment, act like a magnet, and attract all other toxic chemicals, such as pesticides, in the environment, forming a very dangerous cocktail for all kinds of organisms. The ingestion of tiny plastics in aquatic organisms can lead to wounds, impairment of feeding capacity, blockage of the digestive tract followed by satiation and starvation, and general debilitation, often leading to death. In humans, this toxic chemical typically acts as an endocrine disturber [10], and these chemicals are known to cause cancer, diabetes, heart disease, decreased fertility, etc. [11].

Plastic processing has been a flourishing industry in Sri Lanka for over 45 years [12]. According to World Environment Day 2018, Sri Lanka is the 5th largest plastic polluter in the world among countries such as China, Indonesia, the Philippines, and Vietnam [13]. Even go a step further and look at the current issues across the island regarding inadequate and ineffective waste management, such as the devastating garbage dump or illegal dumping, which provides further evidence of the serious nature of this problem. In Batticaloa district, improper municipal dumping actions near the Kattankudy and Eravur lagoon areas, which were part of the Batticaloa Lagoon, led to higher microplastic pollution. However, in Sri Lanka, the presence and distribution of microplastics have been studied in detail in marine ecosystems, and the lagoon system has not received much attention. There is limited available information about microplastic contamination in lagoons compared to that in oceans. As a first step to fill this knowledge gap, this study was conducted to investigate microplastics in lagoon sediments and surface water.

This study focuses on the most convenient techniques and approaches recently applied for the identification of microplastics, and addresses important gaps in knowledge concerning the detection of microplastics. Gathering these data on microplastic pollution can assist in the management of aquatic habitats and inform local, national, and global advocacy for reduced plastic pollution in the lagoon environment. It can also become a tool to help raise awareness and encourage behavioral change that reduces practices that cause microplastic input into the lagoon environment.

2. Materials and Methods

2.1. Criteria for site selection

With respect to Batticaloa lagoons, the impact of some activities, specifically municipal garbage dumping activities, is felt in the loss of scenic beauty and health of the lagoon due to the increased accumulation of plastic waste. It was found to be very extensive in the Eravur and Kattankudy lagoon areas, which are a part of the Batticaloa Lagoon. Therefore, the present study targeted Eravur and Kattankudy as sampling stations based on heavy plastic pollution levels.

2.2. Study period and sample locations

Sampling was conducted from September 2019 to February 2020. Samples were collected once a month in both areas. The geographic locations and related information of the sampling sites are presented in Figure 2.1 and Table 2.1. The locations of the sampling sites were determined using a Global Positioning System (GPS).

Table 2.1. *Geographical coordinates of Eravur and Kattankudy sample stations*

Study sites	Eravur sample station	Kattankudy sample station
	Geographical coordinates	Geographical coordinates
SH_0	7.771091º N,81.601283º E	7.675749º N,81.725922º E
SH_1	7.771081º N,81.601646º E	7.675387º N,81.725967º E
SH_2	7.771072º N,81.602009º E	7.675124º N,81.726211º E
SH_3	7.771071º N,81.602009º E	7.674933º N,81.726518º E
SH_4	7.771179º N,81.602734º E	7.674572º N,81.726518º E
SH_5	7.771151º N,81.603097º E	7.674247º N,81.726363º E

SP_0	7.771000º N,81.601283º E	7.675749º N,81.725831º E
SP_1	7.770991º N,81.601646º E	7.675387º N,81.725876º E
SP_2	7.770981º N,81.602008º E	7.675034º N,81.726183º E
SP_3	7.770981º N,81.602008º E	7.674861º N,81.726464º E
SP_4	7.771088º N,81.602734º E	7.674590º N,81.726427º E
SP_5	7.771060º N,81.603096º E	7.674283º N,81.726245º E
SQ_0	7.770910º N,81.601283º E	7.675749º N,81.725741º E
SQ_1	7.770900º N,81.601646º E	7.675406º N,81.725785º E
SQ_2	7.770890º N,81.602008º E	7.674943º N,81.726156º E
SQ_3	7.770891º N,81.602008º E	7.674789º N,81.726391º E
SQ_4	7.770998º N,81.602734º E	7.674617º N,81.726346º E
SQ_5	7.770970º N,81.603096º E	7.674319º N,81.726136º E

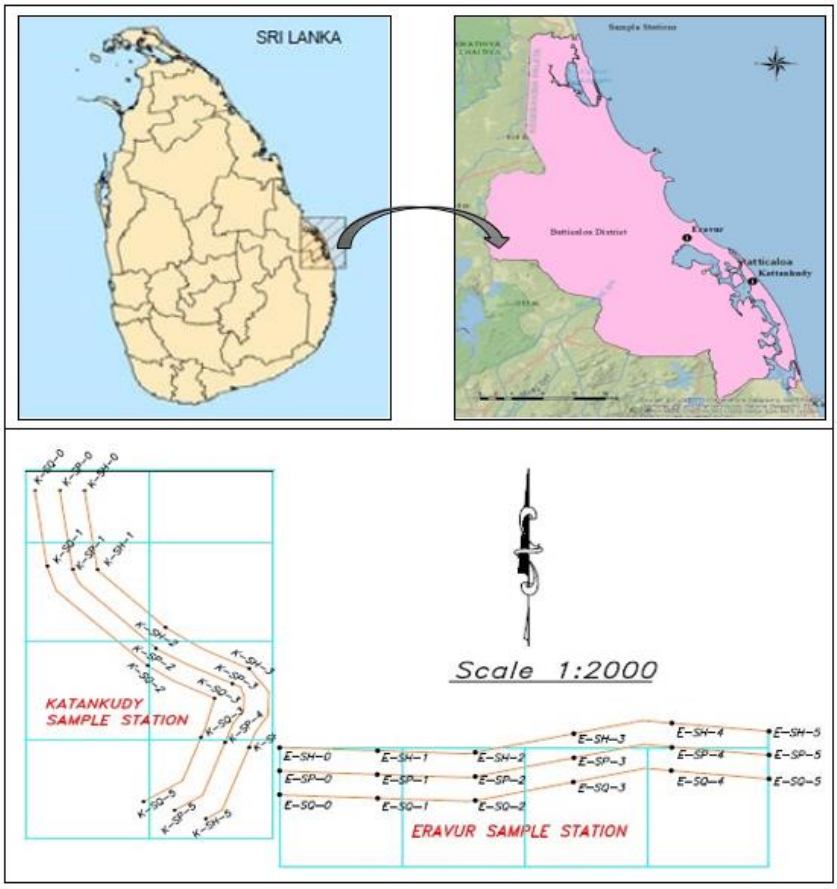

Figure2.1. *Survey map of sample stations*

2.3. Sampling

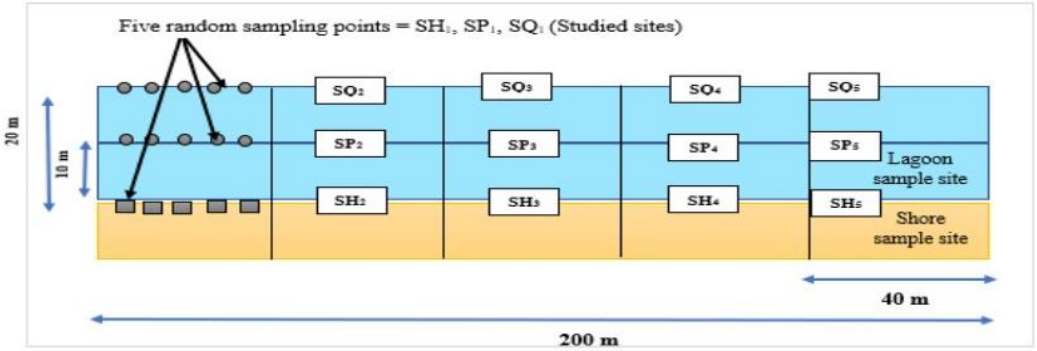

Figure2.2. *Diagrammatic representation of sample collection*

Eravur and Kattankudy were selected as the sample stations. Two hundred meter of shore and lagoon sample sites were selected near the garbage disposal area at both sample stations. The sampling sites were equally distributed as the five study sites; thus, each part covers 40 m and is named SH1 to SH5, SP1-SP5, SQ1-SQ5 in shore, shore to 10 m, and shore to 20 m, respectively. Each study site, surface water, and sediment sample was randomly collected as described in previous studies with minor modifications. Duplicate samples were collected at each study site [14,15,16]

Sediment sample collection: In shore sample sites, five quadrats (0.5 m x 0.5 m) were randomly selected in every studied site. Then, all the top sediments from the marked quadrats were collected with a metallic shovel and mixed to form a single composite sample for each studied site (SH) [16].

In the lagoon sample sites, sediment collection was performed in the same way as the shore sediment sample collection methods. However, instead of a metal shovel, an Ekman bottom-grab sampler was used. The collected samples were named SP1-S to SP5-S and SQ1-S to SQ5-S from the shore to 10 m and 20 m, respectively [17,18].

Surface water sample collection: One-liter surface water samples were collected five times at the sediment collection points and mixed to produce a single composite sample for each studied site. The collected water was filtered through 0.25 mm and 4 mm stainless sieves. All 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 a sample box to avoid shaking and contamination during transportation. Finally, the sample box was transported to the laboratory, Department of Zoology, Eastern University, Sri Lanka, for analysis as quickly as permitted.

2.4. Laboratory Analysis

Each sample was processed using a stepwise approach, including sieving, the wet peroxide method, and density separation to separate microplastics from the sediment and surface water samples.

Sieving: Each sample were sieved by using a stack arrangement of stainless-steel mesh sieves which were 4 mm (5 mesh) and 0.25 mm (60 mesh). Samples were retained on 4 mm sieves and discarded. All solids collected in the 0.25 mm sieve were transferred into a 500 ml beaker. Each beaker was then kept in an oven at 90 °C for 24 h to dry the sample.

Wet peroxide oxidation (WPO): The main aim was to reduce the amount of organic matter present in the sample. To perform the WPO test, 20 mL aq. 0.05 M Fe (II), and 20 mL of hydrogen peroxide were added. To increase the density of the solution, 6 g NaCl was added.

Density separation: A simple density separator is used in this study. It was made from a glass funnel with a segment of latex tubing at the bottom of the stem and a pinch clamp attached to control the liquid flow from the funnel [19]. A saturated NaCl solution (density of 1.20 g cm− 3) was used as a density separator to extract microplastics from the samples.

The Hot Needle Test :This test was useful in cases where it was difficult to distinguish between plastic pieces and organic matter. In the presence of a very hot needle, the plastic pieces melted or curled. Biological and other non-plastic materials are not melted or clued [20].

2.5. Observation and Identification of Microplastics

Each of the treated microplastics from the water and sediment samples was placed in a precleaned petri dish for observation. The petri dishes were placed under a stereomicroscope at magnification 10X for examination, and photos were captured using 8 an pixels camera. Finally, suspected particles were identified based on their morphological characteristics. The identification was based on classification standards from previous studies [21,22,23,24]. The quantity, size, color, and shape of the microplastics were recorded. Abundance was recorded as items/L in surface water and items kg-1 dry sediment. Microplastic size determination was performed using a sieve cascade with mesh sizes of 1, 2 mm,4 mm.

2.6. Quality Assurance and Quality Control

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

2.7. Statistical Analysis

One-way ANOVA was carried out using the Minitab 19 software program to assess the statistical significance of abundance levels among the study sites at both sample stations. Correlation analysis was

carried out between the microplastic abundance and the sample sites, and between the size fractions of microplastics by Pearson correlation. All statistical analyses were checked at the 0.05% significance level. The graphs relevant to the analysis were plotted using Microsoft Excel 2019 software.

3. RESULTS

3.1. Abundance of Microplastics

Microplastics were evident at all study sites at the Eravur and Kattankudy sample stations. The perceived total microplastic abundance with respect to sample sites in sediment and surface water is presented in Table 3.1 and Table 3.2. The abundance of microplastics was statistically significant ($P<0.05$).

Table 3.1. *Total mean (Average ± standard deviation) and range of microplastics abundance in sediment sample sites*

Sediment samples (items/Kg dry weight)			
Sample Sites	**Sample station**	**Mean Abundance**	**Range of Abundance**
Lagoon shore (SH)	Eravur	329.92 ± 22.33	304.5-367.5
	Kattankudy	1033.00 ± 28.80	995.5-1068.0
From shore to 10 m in the lagoon (SP)	Eravur	134.50 ± 9.08	120.0-146.0
	Kattankudy	423.10 ± 29.80	380.0-454.5
From shore to 20 m in the lagoon (SQ)	Eravur	45.42 ± 6.95	38.0-55.0
	Kattankudy	182.75 ± 15.71	162.0-199.5

Table3.2. *Total mean (Average ± standard deviation) and range of microplastics abundance in surface water samples.*

Surface water samples (item/L)			
Sample Sites	**Sample station**	**Mean Abundance**	**Range of Abundance**
Lagoon shore (SH)	Eravur	267.58 ± 15.40	242.5-285.5
	Kattankudy	691.10 ± 28.50	658.0-729.0
From shore to 10 m in lagoon (SP)	Eravur	101.25 ± 6.25	97.0-113.0
	Kattankudy	251. 20 ± 32.30	219.5-296.0
From shore to 20 m in lagoon (SQ)	Eravur	43.50 ± 3.21	38.0-46.0
	Kattankudy	86.08 ± 15.52	66.5-111.5

3.1.1. Comparison of microplastics among sample sites

The level of microplastics decreased from the shore to the lagoon sample sites. At the Eravur sample station, strong correlations of microplastic abundances between shore and from shore to 20 m were evident in sediment and surface water, and they were statistically significant. (Pearson's correlation of sediment = 0.913, p-value =0.000, surface water Pearson's correlation = 0.954, p-value = 0.000). Likewise, in the Kattankudy sample station, Pearson's correlation of sediment = 0.725, P =0.000, and in surface water, Pearson's correlation = 0.547, p value = 0.002.

3.1.2. Comparison of microplastics abundance between sample stations

A high abundance of microplastics was observed in Kattankudy from both sediment and surface water, consisting of 76.19% and 71.38% MPs, respectively. However, at the Eravur sampling stations, 23.81% of MPs were in sediment samples and 28.62% of MPs were in surface water samples. This is illustrated in Figure 3.1.

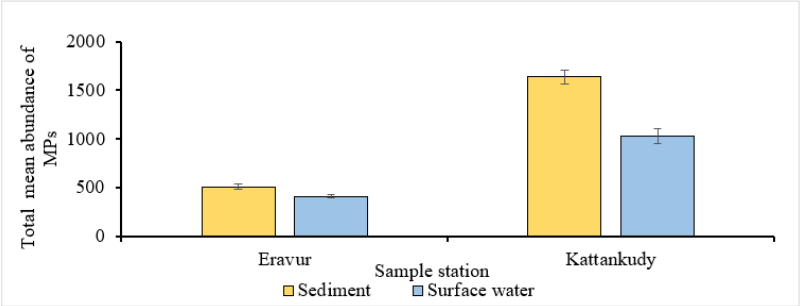

Figure3.1. *Comparison of microplastics between sample stations*

3.2. Shape of Microplastics with Abundance

All types, including primary and secondary microplastics, were found both in the sampling stations, and the morphological characteristics of the observed microplastics are summarized in Plate 1.

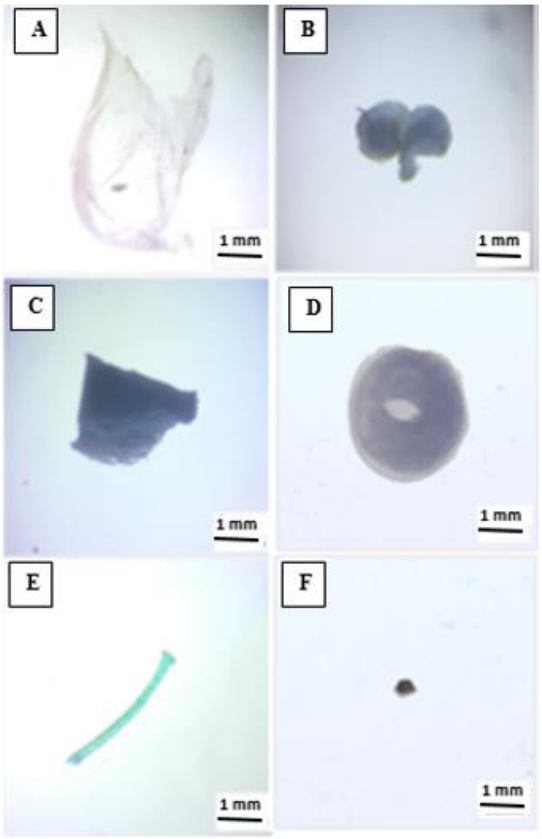

Plate1. *Different shapes of microplastics magnified into 10 times: Films (A); Fragments (B); Filaments (C); Foams (D); Pellets (E); Microbeads (F).*

3.2.1. Comparison of Microplastic shapes in between sediment and surface water

Compared to the Eravur and Kattankudy sample stations as a whole, fragment types at both stations were higher in sediment than in surface water. Film types were found more frequently in surface water than in sediment samples. Filaments were more common in the surface water and sediment. Similar to filaments, the diffusion of foam did not show much difference in surface water and sediment. The level of microbeads was found to be low at both stations. Pellet forms were recorded only in the sediment samples from both stations (Figure 3.2).

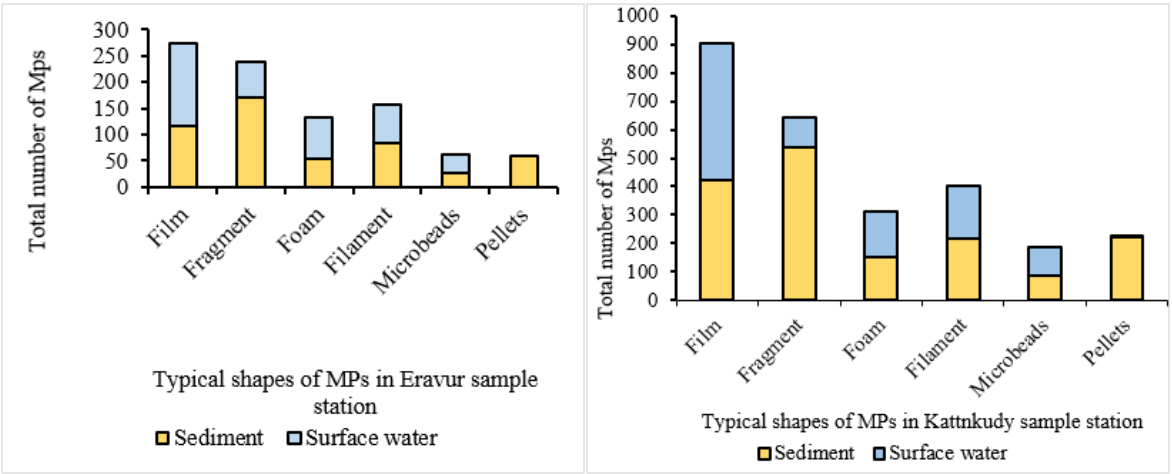

Figure 3.2. *Comparison of Microplastic shapes in both sample stations*

3.3. Colour of Microplastics

A variety of colors were found in the microplastics collected from both the surface water and sediment (Figure 3.3) at both stations.

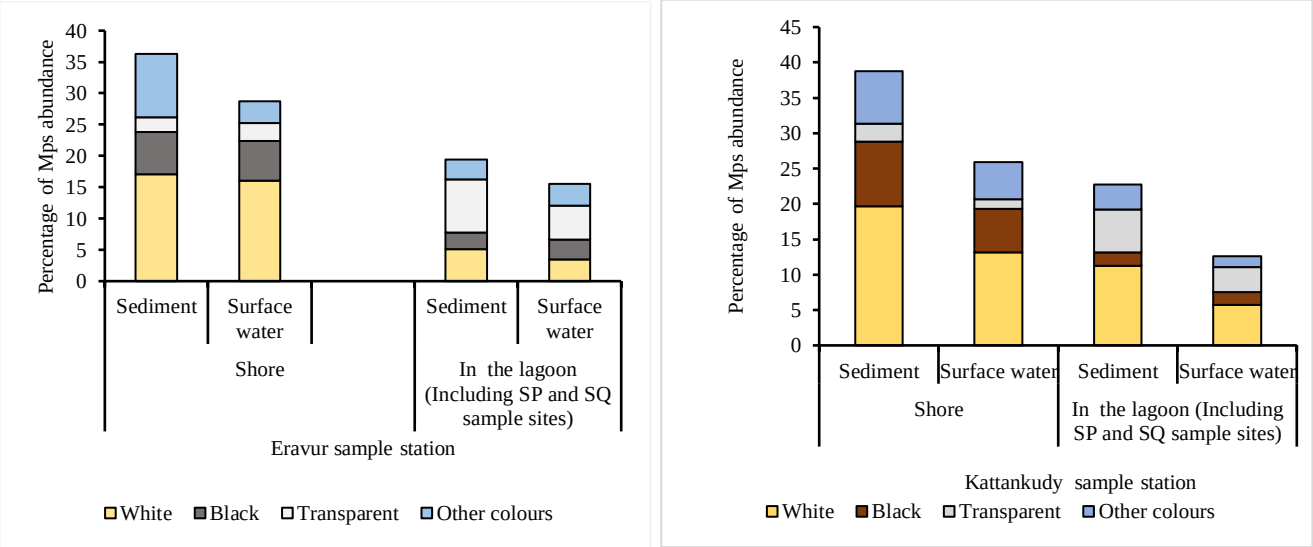

Figure3.3. *Colour of microplastics both sample stations*

Large quantities of white microplastics were found in both shore sediment and surface water. Next, black microplastics were observed. White and transparent colors were observed in the lagoon.

3.4. Size of Microplastics

At each study site, three small categories (<1 mm,1 -2 mm,2 -4 mm) were recorded. At both sample stations, the size of microplastics varied between sediment and surface water (Figure-3.4). A tendency toward larger microplastic quantities in smaller mesh sizes was observed in the sediment samples from both sample stations. The number of microplastics in the surface water samples increased with increasing mesh size.

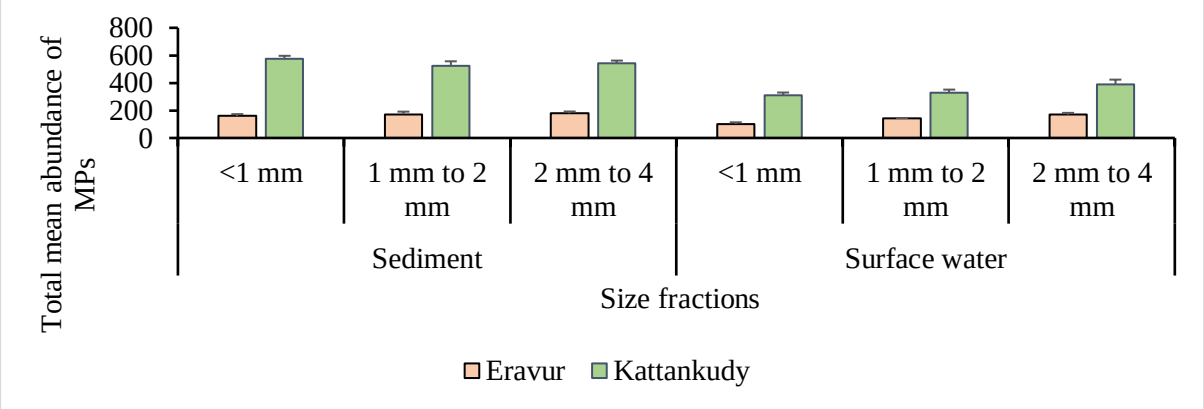

Figure 3.4. *Size fraction comparison between sediment and surface water in sample stations.*

The size fractions of the microplastics were also analyzed using Pearson correlation. In Kattankudy, the quantity of microplastics was strongly correlated and statistically significant among the different size fractions of microplastics. These values were <l mm and 1 mm to 2 mm (Pearson's correlation = 0.877, P = 0.022), <l mm and 2 mm to 4 mm (Pearson's correlation = 0.744, P = 0.090), l mm to 2 mm and 2 mm to 4 mm (Pearson's correlation = 0.935, P = 0.006) for surface water and <l mm and 1 mm to 2 mm (Pearson's correlation = 0.904, P = 0.013), <l mm and 2 mm to 4 mm (Pearson's correlation = 0.626, P = 0.184), and l mm and 2 mm to 4 mm (Pearson's correlation = 0.790, P = 0.062) for sediment.

Likewise, in Eravur, fractions less than 1 mm in size were weakly correlated with 1 mm to 2 mm (Pearson's correlation =0.108, P value = 0.839) and 2 to 4 mm (Pearson's correlation = 0.004, P value

= 0.993). In addition, a non-significant relationship is evident between these fractions. A slightly strong correlation and non-significant relationship was evident between 1 mm to 2 mm and 2 mm to 4 mm (Pearson's correlation = 0.578, P value = 0.229) for surface water, and the 1 mm size fraction of microplastics was negatively correlated with 1 mm-2 mm (Pearson's correlation = -0.346, P value = 0.502). and 2–4 mm fractions (Pearson's correlation = -0.327, P = 0.526). A non-significant relationship was also evident between these fractions. However, a Positive correlation and statistically significant results were evident between the 1 mm to 2 mm and 2 mm to 4 mm size fractions (Pearson's correlation = 0.844, P value = 0.035) for sediment samples.

4. DISCUSSION

4.1. Microplastic Distribution and Pollution Level

Comparing the results from Table 3.1 and 3.2, the highest abundance of microplastics was found in shore sites compared with shores from 10 m and 20 m in the lagoon (Figure 3.1). This location continues to function as a dumping ground for garbage, and human interference is also higher than that of lagoon sample sites [16,25]. Inside the lagoon, hydrodynamic conditions (wind, water current, tidal actions) may influence this distribution pattern [16,26]. For example, a strong water current makes it difficult for microplastics to sink or stay in the lagoon environment for a long time. However, the hydrodynamic distribution of microplastics requires further research [27].

The highest number of microplastics was recorded in all sediment and surface water samples at Kattankudy compared to the Eravur sample station. Most previous studies have linked population size with abundance[16]. A higher contamination level was observed in densely polluted areas such as the Kattankudy sample station. Normally, this Kattankudy sample station acts as a garbage dumping site; therefore, continually more and more rubbish is being dumped in these places, as in Eravur, but here a large proportion of the human population inhabits these coastal areas, and people use these places as sinks to their everyday household waste. In addition, many people living around the lagoon depend on fishing for their livelihood [27,28]. Therefore, heavy human pressure also leads to the release of plastic litter into this environment [16,29]. The above discrimination activities were the key contributors to microplastic contamination and contributed to the loss of scenic beauty and health of the Kattankudy Lagoon.

However, at the Eravur sample station, human settlements were found beyond a certain distance. Therefore, the accumulation of household waste is low every day. The main sources of plastic pollution are garbage dumping and fishing activities. The Eravur Lagoon Park system may also contribute to the accumulation of plastic waste due to the improper disposal of plastic items by park visitors. However, the Eravur sampling statin contained a low amount of microplastics compared to the Kattankudy sample station.

Higher numbers of microplastics were observed in the sediment samples than in the surface water samples at both sampling stations. wave action and water currents were very low in the lagoon environment; thus, the breakdown of microplastics was also low. Therefore, most of the plastic particles were trapped in the sediment and degraded to form microplastics in the sediment rather than floating in the surface water [26].

4.2. Shape of Microplastics and their Sources

Overall analysis of sediment and surface water indicated that fragments and film types of microplastics were more abundant in the shore than in the lagoon sample sites (Figure 3.2). Municipal dumping activities in shore areas were the main sources of this type of accumulation. Large quantities of microplastics are produced by disposable packaging, which has been used to express delivery and takeout food, both of which have boomed in recent years. Therefore, the dumping sites consisted of a greater amount of disposable packaging. Plastics are easily broken into plastic fragments or films. Therefore, more films and fragments were observed on the shore. [16,30]. A considerable number of pellet forms are also present owing to the dumping actions. In addition, some filaments and foams were found in the samples because of fishing tools, such as fishing nets and regiform boxes [16,18]. Microbeads are more common in Kathankudy than in Eravur stations because of the presence of concentric household waste and poor drainage systems [16,31].

Compared to the Eravur and Kattankudy sample stations as a whole, fragment types at both stations were higher in sediment than in surface water. This was because more fragments were found to be denser than water, so they remained in water. However, some fragments float in surface water because

they are less dense than water [25,32]. At both stations, more film types were found in the surface water than in the sediment samples. This is because the film is less dense than water. However, some films were denser. They were found to be entangled in sediments. Therefore, a significant number of films were felt in the sediments. The next films had the ability to move easily in water; therefore, their spread was more visible in water [32].

Filaments were more common in the surface water and sediment. This is because they are more likely to float in water. As it is normally less dense, this is also significantly observed in the sediments. A few authors [31,33] have also found plastic filaments to be the most common type of microplastics present in sediment samples. The filaments were preferentially removed from the suspension as they were trapped between the settling sand grains. Owing to the elongated size of the filaments and the very large surface-area-to-volume ratio, it is more likely to impact and drag downward [34]. Foam usage was observed to some extent because of the significant number of fishing practices. Similar to filaments, the diffusion of foam did not show much difference in surface water and sediment. It also relies on low density. However, some foam is present in the sediments. This is because it may have been accidently buried in sediments.

Pellet forms were recorded only in the sediment samples from both stations. However, this was not observed in any of the surface water samples. The pellets were found to be denser than water and thus unable to float in surface water [25,32]. The level of microbeads was found to be low at both stations. This is because microbeads are easily soluble in water, can stay in water for a short period of time, or they may not realize this. This is because most microbeads were too small in size.

4.3. Colour of Microplastics

Large quantities of white microplastics were found in both shore sediment and surface water. The main reason could be that the true color of the plastic on the shore may be under go discoloration due to other factors, such as longer exposure time to sunlight, which can cause the natural degradation of microplastics by ultraviolet radiation; thus, plastics lose their original color and fade [35]. Next, black microplastics were observed due to high contamination, making these plastics appear black or dull.

White and transparent colors were observed in the lagoon. Because a large number of transparent plastics are commonly used in fishing nets and lines, and white Regi forms are used for frequent fishery activities, this color was more likely to be present [36]. Transparent microplastics in sediment samples may be attributed to bleaching caused by digestion [25].

4.4. Size of Microplastics

A tendency toward larger microplastic quantities in smaller mesh sizes was observed in the sediment samples from both sample stations. This result is consistent with those of previous studies [18,37]. The main cause of the prevalence of smaller microplastics is the fragmentation of larger plastics present in estuarine environments. Larger plastic litter rapidly begins to degrade into smaller fragments as a result of physical variables (salinity, light, temperature, and humidity) and microbiological degradation [38]. Thus, large plastic fragments can produce hundreds or thousands of microplastics in the lagoon environment. Moreover, sediments with the highest proportion of finer fraction microplastics tended to be more cohesive and flocculated regularly. This is why microplastics may be retained in the sediment during flocculation of particles [37]. This is likely to affect the suspension and deposition behavior of microplastics [34]. The number of microplastics in the surface water samples increased with increasing mesh size. This conclusion is consistent with those of previous studies. A possible explanation is that large plastics are prone to flow and wind forces, leading to floating on water, whereas smaller plastics tend to migrate into sediments and deep water [25].

5. CONCLUSION

The method presented in this study for quantifying, separating, and identifying microplastics produced a variety of results from sediment and surface water samples. There was a notable difference between the Eravur and Kattankudy sample stations due to the total microplastic abundance level, microplastic distribution across different sediment fractions, and proportions of different types and colors of microplastics. A higher abundance of microplastics was observed at the Kattankudy sample station (~74%) than at Eravur (~26%). Therefore, the levels of microplastic pollution were too high at the Kattankudy sample station. This leads to the loss of scenic beauty and health of the lagoon. The results of this study highlight the importance of microplastics in brackish water ecosystems. Without proper

future precautions, these ubiquitous contaminants will become a vital force and destroy the environment.

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