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***Research Article** (Open Access)*

OCCURRENCE AND DISTRIBUTION OF MICROPLASTICS IN THE SHORE SEDIMENTS OF THE KOSASTHALAIYAR RIVER IN CHENNAI

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ABSTRACT

Microplastics loaded with pollutants would sink and concentrate in sediments, generating a higher concentration in this compartment and raising the toxicological risk for benthic animals. In the present study, the shore sediments were analysed for microplastic accumulation in the Kosasthalaiyar River, Chennai. The sediments were collected and processed for microplastic analysis. The microplastics were identified using a wet peroxide oxidation and density separation method. The sampling could be done at different sites in the Kosasthalaiyar River and Ennore Estuary (n = 17). The highest concentrations of microplastics were found near the estuary region, at 470 items per kg of dry weight. The Kosasthalaiyar River is one of the major rivers, and it merges into the Bay of Bengal. The shape, colour and size of the retained microplastics were determined. Scanning electron microscopy (SEM) was used to assess morphological changes on the plastic surface caused by the degradation process.

Keywords: *Microplastics; Shore sediments; Kosasthalaiyar River; Ennore Estuary; SEM analysis; Impact*

INTRODUCTION

For a variety of economic and environmental reasons, plastics are a significant cause for concern (Klein, 2015). Plastic endures in the environment for a very long time, affecting species and dispersing pollutants. The rise in microplastic pollution and its impact on humans are grabbing attention (Zhang *et al*., 2018a, b). According to Horton *et al*. (2017), plastic particles categorised as mega-debris were 100 mm, macro-debris were 20 mm, meso-debris were 20–5 mm, and micro-debris were less than 5 mm. UV radiation degrades plastics into microplastics with diameters of 5 mm or less (Andrady, 2011). Microplastics can be found in environmental samples in a variety of configurations, including fibre, spheres, and pieces, because they are the result of many sources (Vianello, 2013). Primary microplastics with a size of 5 mm and disintegrated products known as secondary microplastics represent types of microplastics (Wen *et al*., 2018a). According to de Souza Machado *et al*. (2018) and Zhang *et al*. (2020 b), the microplastics are produced from the initial form of primary microplastics, the erosive and degrading processes that occur on the plastic particle surface, and the long dwell time of particles in the environment. Microplastics could be created indirectly by the fragmentation of bigger plastics, or they could be produced directly as exfoliants in cosmetics (Napper *et al*. 2015), or they could be (Andrady 2015). Organic pollutants may be transported through microplastics. These pollutants may be present in the polymers as additives or monomers used in the manufacture of plastics, or they may adsorb to the plastic from the surrounding water (Rochman, 2013). Plasticizers, fire retardants, and other additives are used to improve the performance of plastic items. These compounds can be discharged into the environment, posing serious ecological hazards (Liu *et al*., 2019). Microplastics, being too small and resembling other microorganisms such as plankton, pose a greater risk of being consumed by ocean creatures (Su *et al*., 2019). From the results recorded, it was identified that plastic pollution, including MPs, either directly sinks through the water column or accumulates indirectly as a result of currents and sediments being moved down continental slopes (Clark *et al*., 2016). Freshwater bodies have a significant role in the transportation of microplastics (Jiang *et al*., 2019). Several investigations on microplastics in freshwater environments have been published in recent years, with the majority focusing on developed regions that attract significant human activity (Giovacchini *et al*., 2018; Wang *et al*., 2018a, b; Wen *et al*., 2018a, b).

Rivers transfer a tremendous amount of plastic waste to coastal habitats (Horton *et al*., 2016; Wagner *et al*., 2019). Rivers have a significant impact on the transportation of plastic into lakes, seas, and oceans (Dris *et al*., 2015; Lebreton *et al*., 2017; Schmidt *et al*., 2017). The connectivity of urban areas and river runoff has frequently been related to high microplastic concentrations in surface waters and beach sediments (Robin *et al*., 2019). It is currently acknowledged that the most majority of plastic entering the seas originates on land, with only a small amount created directly at sea by shipping, platforms, and fisheries (UNEP 2016). Although it is believed that 70 to 80% of marine MPs originate on land, rivers are often underestimated as a source of MP pollution (Akdogan and Guven, 2019; Klein *et al*., 2015; Mani *et al*., 2015). In 2015, approximately 8 million metric tons of plastic garbage were estimated to have been dumped into the ocean from land, with this proportion predicted to increase to approximately 32 million MT by 2050 (Crawford and Quinn, 2017). Analyzing sediment samples is useful for determining the long-term deposition of microplastics in aquatic ecosystems (Peng *et al*., 2018). Plastic with a density greater than 1.0 g/cm^3 should naturally sink and deposit in the sediment, whereas low density debris should float on the water's surface or in the water column (Alam *et al*., 2019; Peng *et al*., 2018). Biofouling could drive the particles to settle onto the seabed by increasing their density and weight (Firdaus *et al*., 2019). Pollutants from a variety of anthropogenic activities, including housing, agriculture, aquaculture, boating, and fishing, may end up in the estuary (Nithin *et al*., 2022). According to Chang *et al*. (2010), wastewater treatment plant (WWTP) discharges, garbage dumps, agricultural runoff, the textile and cosmetics industries, as well as fishing operations, are the main human-caused sources of microplastic contamination in estuaries (Daniel *et al*., 2020). These plastics reach marine environments either directly through anthropogenic activities (such as aquaculture, fishing, shipping, or tourism) or indirectly through rivers and sewage outflow (Tagg *et al*. 2015). In most cases, wastewater is dumped into drainage canals, which eventually end up in the river (Firdaus *et al*., 2019). The objectives of the study are to (i) analyse the distribution and concentration of microplastics in the sediments collected at the Kosasthalaiyar River and its Mouth Ennore Estuary (ii) Determine the shape, colour, and size of the discovered microplastics. (iii) Discussed about the impact of microplastics in sediments.

Figure 1: Geographical location of sampling stations in Kosasthalaiyar River

MATERIALS AND METHODS

Study Area

Kosasthalaiyar River is one of the three major rivers in the Chennai. It has the large catchment area of 1365 sq.km. The river joins the Bay of Bengal through Ennore Creek and Pulicat Lake (India's 2nd largest brackish water body). This river flows from west to east, originating in the mountains and finishes in the Bay of Bengal. The river is essentially ephemeral in nature, streaming only during a portion of the year, mostly from November to February (Jagadeshan *et al*., 2015). The creek receives wastewater from the industrial area in Manali, the domestic sewage through the Buckingham Canal and the factory effluents from the coal power plants (Padma and Periakali, 1998; Jeyaprakash *et al*., 2012). The river runs from the Poondi Reservoir through the Thiruvallur district, into the Chennai metropolitan area, and joins with the sea in the Ennore Creek (Krishnamoorthy *et al*., 2020).

Sample Collection

For the microplastic study, various sampling techniques, sample treatment procedures, and segregation methods were used (Rezania *et al*., 2018). However, in freshwater habitats, the range of banks or shoreline seems to be much smaller compared to the ocean, hence sample locations might be considerably nearer to rivers and lakes (Yang *et al*., 2021). The sediments were sampled at seventeen distinct points along the Kosasthalaiyar River (Fig.1). At each site, sediment was collected with a stainless steel spoon in a 1m quadrate at a depth of 2-3 cm. After collecting the sample from each sampling site, it was weighed up to 1 kg (wet weight) prior to laboratory examination. Individual zip-lock bags were used to seal the acquired sediment samples. The zip-lock bags were stored for further examination.

Sample Processing

The dry weight of each sediment sample has been determined by drying and weighing a subsample of 100 g (wet weight) in room temperature for 2 - 3 days until completely dehydrated. Finally, a 100 g dry sediment sample was weighed and placed in a pre-rinsed glass beaker (Peng *et al*., 2018). The sediment sample is treated with a high-density salt solution, which causes low-density particles like the microplastics to float on top of the solution and then separates them (Li *et al*., 2018; Stock *et al*., 2019). The density separation was performed using a saturated sodium chloride solution. The sediment was uniformly shaken for 5 minutes, after which the solution was kept for flotation. After agitating, samples were left standing until no more visible material floated in the supernatant (Alam *et al*., 2019). The supernatant was filtered through a 25 micron metal mesh and transferred to another beaker when it had settled. Finally, the mesh was flushed with milliQ water to collect the retained particles and perform the digestion process (Tsering *et al*., 2021). For each sediment sample, this isolation method was repeated twice (Sruthy and Ramasamy, 2017). Wet peroxide oxidation method was used to reduce the organic content of the supernatant particles (Scherer *et al*., 2020). To eliminate natural organic particles, 100 g of sediment sample was treated with 30% of hydrogen peroxide (Sathish *et al*., 2019). After digestion, Density separation was performed to filter the clear supernatant through membrane filter papers of 0.2micron. Before further analysis, the filter papers were dried at room temperature.

Observation and identification of microplastics

The filters were then photographed, and the shapes, sizes, and colours of the particles were obtained using a stereozoom microscope (Fig. 2a). Samples were examined under a stereomicroscope (SMZ 25) equipped with a digital camera to identify the type of microplastic. The microplastics found in this investigation could be divided into five categories. (i) Fiber is a long and thin microplastic; (ii) fragment is a tiny piece or part of a larger plastic item; (iii) pellet is an ovoid sphere form, disc-shaped, or tubular ;(iv) film is a piece of plastic waste with a very thin surface; and (v) Styrofoam is light tough polystyrene foam. A microplastic is considered as a fragment that cannot be classified as a fibers, pellet, film, or Styrofoam (Di and wang, 2018). Fourier-transform infrared spectroscopy (FTIR) is commonly used to identify microplastics (Zhang *et al*., 2018a). Selective plastic particle samples collected from filter paper are used for ATR-FTIR analysis (Natesan *et al*., 2021). In this study, Polyethylene terephthalate (PET) (Djebara *et al.,* 2012), Polypropylene and Nylon were detected (Fig. 2b). Absorption peaks identified in the software using a peak height method were recorded and compared to absorption peaks described in the literature for each polymer. The polymer

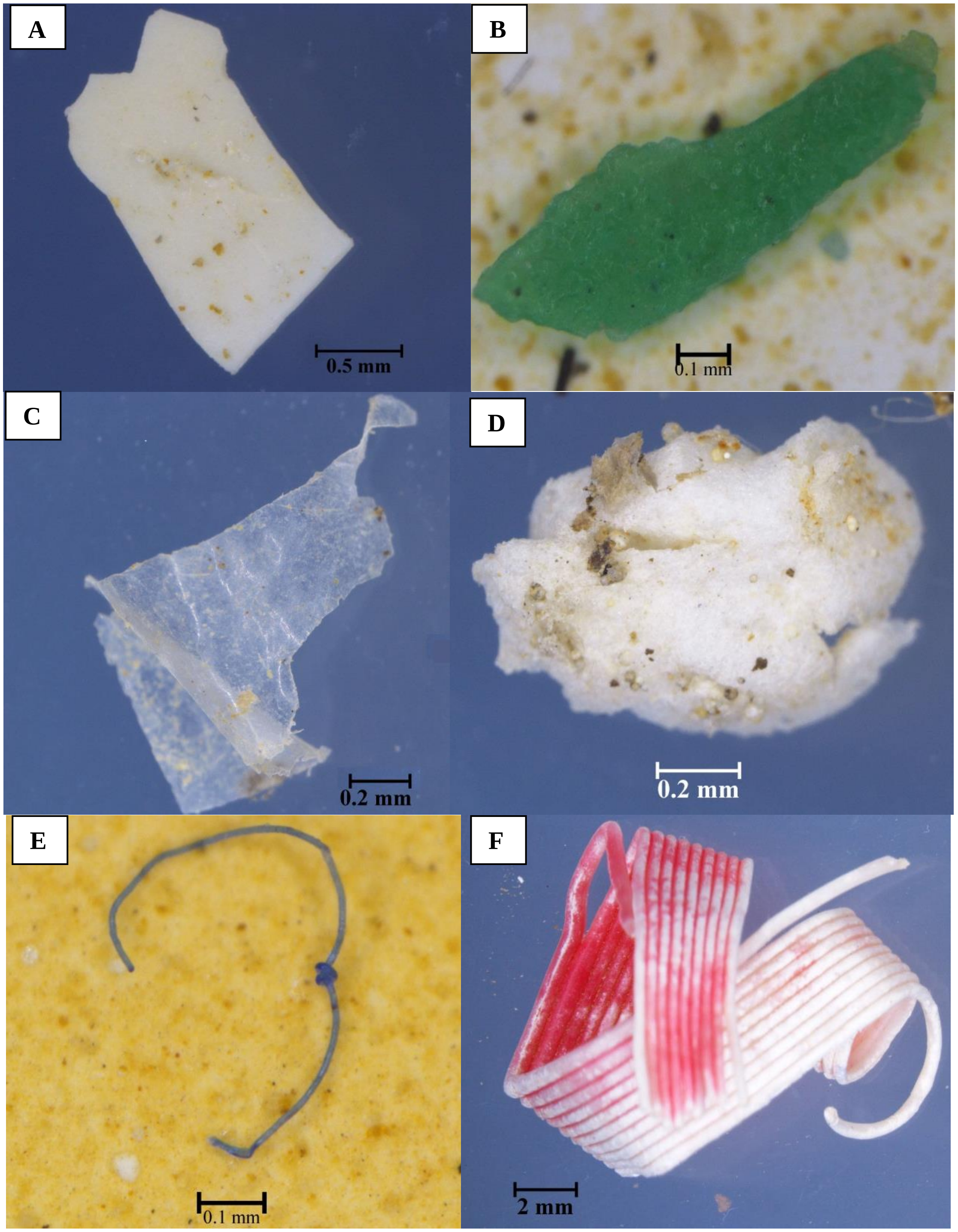
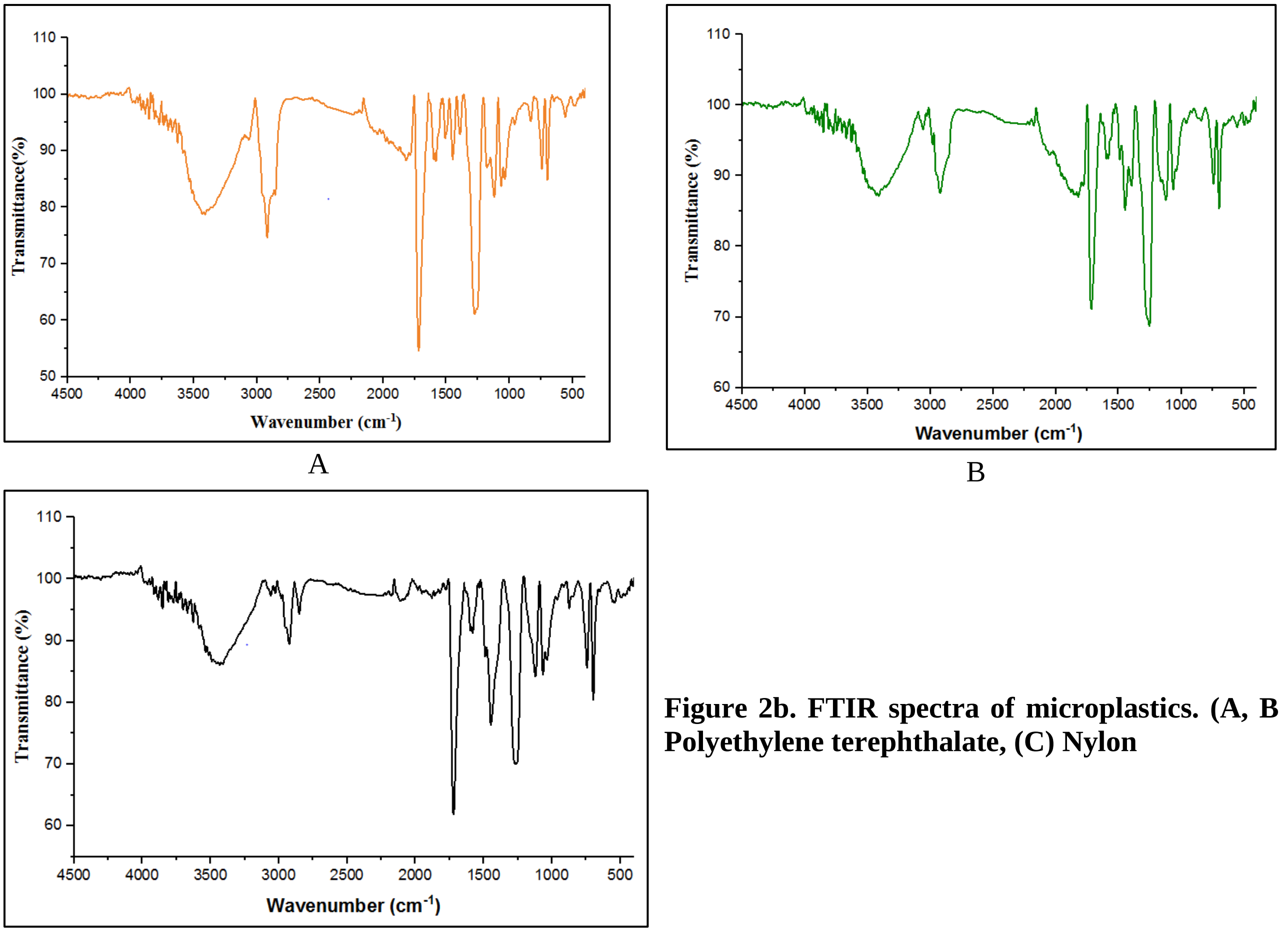


Figure 2a. Photographs of microplastics collected from the sediments of Kosasthalaiyar River Microplastics (A – E); fragment (A, B), film (C), foam (d), fiber (E) and macroplastic (F)



A

B

C

Figure 2b. FTIR spectra of microplastics. (A, B) Polyethylene terephthalate, (C) Nylon

identification needed the four matching absorption bands (Jung *et al*., 2018; Noda *et al*., 2007). The major peaks discovered in polymer materials were 1716.649 Cm-1 (CH3 bend, C=O stretch), 1255 to 1037 cm-1 (CH2 bend, C=C stretch, and C-O stretch), and 697.78 cm-1 (NH bend, C=O bend), and these assignments are classified by Nylon (all polyamides) type of polymer (Natesan *et al*., 2021). PET can be used in the production of polyester, bottles, and electronic equipment (Liu *et al*., 2022). Leslie *et al*. (2022) detected PET plastic in half of the blood samples of volunteers. They pointed out that PET plastic is frequently employed in the production of beverage bottles. The scanning electron microscopy (SEM) was used to assess morphological changes on the plastic surface caused by the degradation process using high-resolution imaging (Fig. 2c) (Khoironi, *et al*., 2020). The SEM pictures revealed several disintegration features (Sekudewicz *et al*., 2020). Pits, cracks, flakes, and adhering particles were the most common degraded patterns, which were mostly caused by mechanical abrasion such as wave action and sand grinding (Wang *et al*., 2017). SEM imaging revealed that oxidation textures were concentrated within and near deep fractures and pits (Zbyszewski *et al*., 2011). Plastic particle degradation is more likely to occur on land than in the oceans, where UV light and mechanical erosion are negligible (Gregory and Andrady, 2003). The oxidation caused by solar UV radiation enhanced plastic degradation, combined with abrasion, resulted in breakages along cracks, finally leading to plastic embrittlement. All statistical analysis was performed using MS Excel 2010. Origin 2023 software was used to plot the graph.

Only glass beakers and metal sieves were used to prevent contamination during sample processing. The workspace and equipment were thoroughly cleaned with deionized water. To reduce contamination, samples were treated in a fume hood, wearing white cotton laboratory coats and latex gloves. Throughout the process, the laboratory containers were washed thrice with the milli Q water and all the samples were always wrapped in aluminium foil. Blank trials were carried out to ensure that there was no external microplastic contamination.

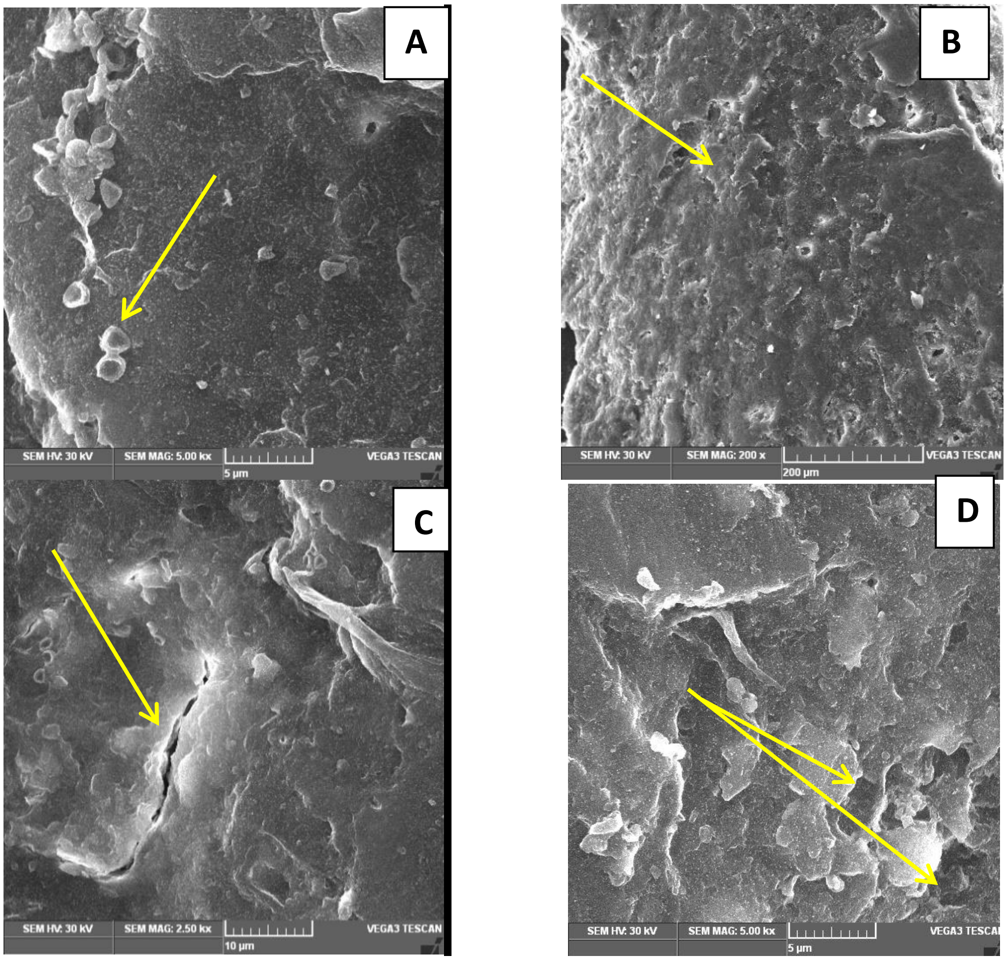


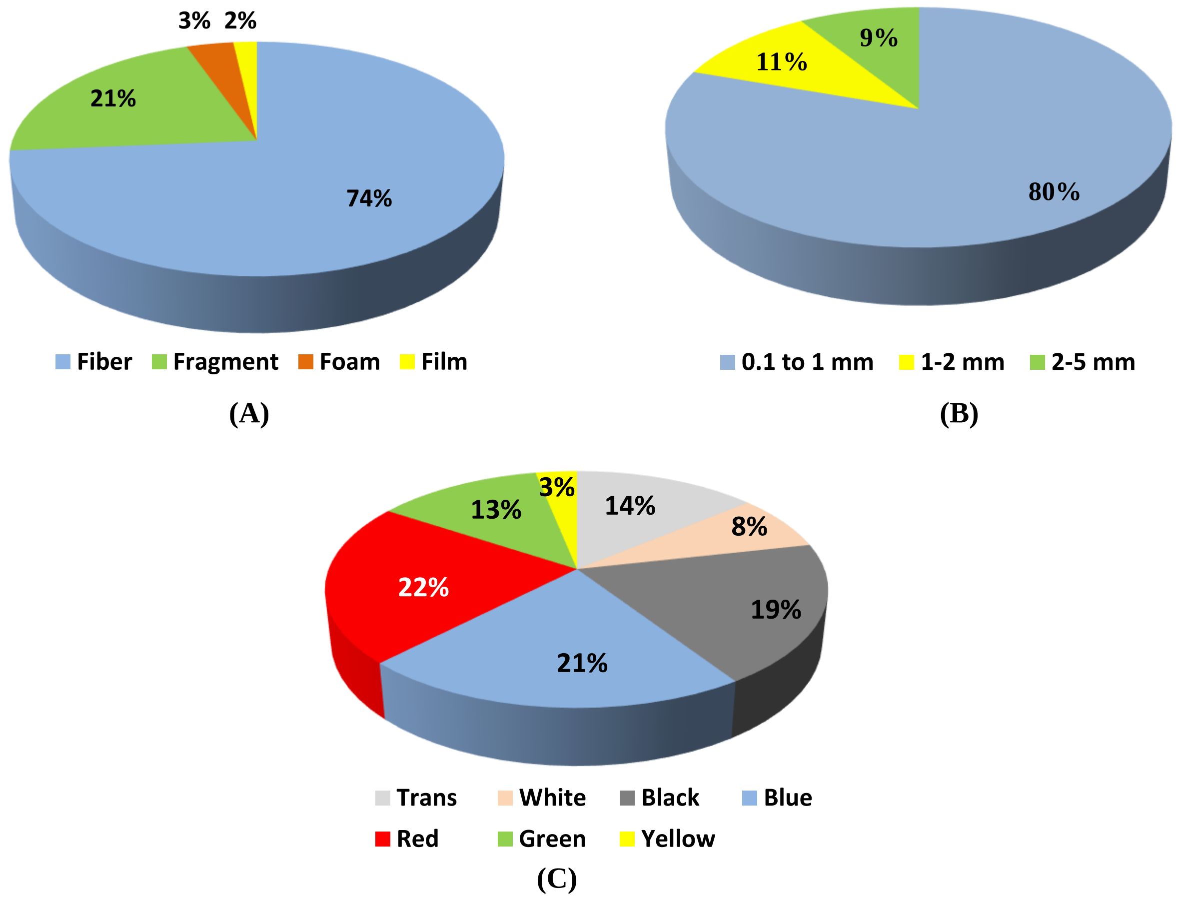
Figure 2c. Examples of surface textures on sampled plastic particles. (A) Granules, (B) Flakes (C) Fracture and (D) Pits

Quality Control

RESULTS AND DISCUSSION

Occurrence of microplastics

The abundance of microplastics in the sediments of the Kosasthalaiyar River was detected in the study. The occurrence of microplastics in the sediments of this River ranged from 10 items /kg (Station 1) to 470items / kg (Station 15). The Sediment had an average abundance of microplastics of 132.94 ± 170.87 items / kg in the Kosasthalaiyar River. The investigation carried out in Poland's Vistula River reported that the particle concentrations ranged from 90 items kg^{-1} (site 1) to 580 items kg^{-1} (site 2) (Sekudewicz *et al*., 2020). The abundance of microplastics in the sediments of China's Qin River ranged from 0 to 97 items kg^{-1} dry weight (Zhang *et al*., 2020b). Microplastics were found at all sites except SLC-S and were most numerous in SLC-E (563 ± 1219 items/m^2) in the remote lakes of Tibet Plateau. The standard deviation of microplastic abundance from sediment samples from each sampling site was significant, indicating a heterogeneous lateral distribution patter (Zhang *et al*., 2020a). The microplastics concentration of shore sediments in Lake Ontario reached 27,830 items / kg^{-1} dry sediment, the highest documented value among near shore sediments worldwide (Ballent *et al*., 2016). The maximum amount of MP found at site 5 was (590 particles kg^{-1} DW), followed by the second highest (484 particles kg^{-1} DW) at site 4. Both locations were in the sea (Firdaus *et al*., 2019). The abundance of microplastics in Yangtze Estuary sediment ranged from 20 to 340 particles kg^{-1} (dry weight) (Peng *et al*., 2017). As a result, minimize the amount of plastic waste, enhancing river management, and increasing river water quality will be beneficial in reducing the abundance of microplastics near the source (Zheng *et al*., 2019). Microplastic pollution migrates to groundwater systems through underground flow and has a negative impact on freshwater ecosystems. Plastic particle accumulation in groundwater was higher within a one-kilometer radius of the dumping sites. Human consumption of microplastics through drinking water was estimated to be 0–4.7 x 10^3 items, while inhalation was estimated to be 0–3.0 x 10^7 items per person per year (Natesan *et al*., 2021).



(A) (B) (C)

Figure 3. Morphological form of microplastics (A) Shape, (B) Size and (C) Colour

Morphological Characteristics of microplastics

The investigation conducted on the Kosasthalaiyar River confirmed that the microplastics possessed varied morphological features such as color, shape and size (Fig. 3). The attractive colours, together with its small size and high buoyancy, make the MP available to fish (Chatterjee and Sharma, 2019). In the present study, red predominates (22%), followed by blue (21%), black (19%), transparent (14%), green (13%), white (8%), and yellow (3%) in Kosasthalaiyar River sediments. The dominant hue in surface sediments of urban water in Changsha was transparent. Plastic bags, which are widely used by humans in their daily lives, may be a source of transparent microplastics (Wen *et al*., 2018 a). The proportion of fibers in sediments was higher, ranging from 33.9% to 100% (Di *et al*., 2018). The toxicity of microplastic pollution is influenced by its shape and size; smaller microplastic is typically more hazardous to aquatic species due to its potential availability to a broad spectrum of organisms (Akkajit *et al*., 2021). In this study, the fibers attained the maximum amount (74%), followed by fragments (21%), film (4%), and foam (1%). The majority of fiber shapes were most likely created using textile materials and fishing gear (Andrady, 2017). Clothes are one source of microplastic fibers in the environment (Dodson, *et al*., 2020). Each wash in a normal household washing machine might result in over 1900 fibers from a single item of clothing. It is significant to highlight that up to 80% of the microplastic fibers detected in beach sediments around the world have a direct link to such washing machine discharge (Browne *et al*., 2011). The high proportion of fibers found in beach sediments along the Phuket coastline is consistent with previous research that observed a high proportion of fiber microplastics on the west coast of Phuket from the washing of synthetic clothing, parts of rope, damaged safeguard lines, and all fishing equipment (Akkajit *et al*., 2019). Household wastewater contains a significant amount of microplastics, particularly microbeads and synthetic fibers (Zhang *et al*., 2018a). Fibrous microplastics were dominant in the sediment samples of Jiaozhou Bay estuaries, accounting for 86.96 % (Zheng *et al*., 2019). The films and Styrofoam can be generated by fragmenting commonly used packaging goods and plastics containers (Nor and Obbard, 2014; Di and wang, 2018). The origin, shape, and mass production of plastic particles that float in the sea appear to be similar to those of mobile plastic debris in rivers (Schmidt *et al*., 2017). The size percentages of microplastics observed on the shore sediments of the Kosasthalaiyar River and the Ennore Estuary were 80% (0.1 to 1 mm), 11% (1 to 2 mm), and 9% (2 to 5 mm). The grain sizes of sediment are similar to the size fraction of microplastics (or even smaller), and microplastics can be consumed not only by lower trophic-level creatures that grab nearly anything of the suitable size class but also by other sediment-dwelling organisms (Moore, 2008; Wright *et al*., 2013a).

Impact of micoplastics on sediments

The physical features of the soil were changed by the small form of plastic known as microplastics. Microplastics are consumed by micro- and mesofauna such as mites, collembola (springtail), and enchytraeids and hence accumulate in the soil's detrital food web (Rillig, 2012). Due to a lack of adequate management, some domestic plastic garbage forms a scattered source of MPs (VanWijnen *et al*., 2019). Leaching is the most prominent method of introducing microplastics into the soil and even groundwater (Rillig *et al*., 2017a). Microplastics in topsoil may also reach deeper soils through numerous processes, such as agricultural cultivation, soil cracks, or soil organism disturbance (He *et al*., 2018). Migration of soil organisms could also promote the transmission of microplastics between strata (from shallow to deep soil, or vice versa) (Wang *et al*., 2021). In many cases, the microplastic was significantly smaller than the birds usual food, indicating that microplastic intake was either incidental or owing to trophic transfer. Through the research work on the first report of terrestrial birds ingesting minute anthropogenic particles, it was found that the average number of objects detected per bird was 10.6 ± 6.4, which shows the relative pollution level in the research area's terrestrial ecology (Zhao *et al*., 2016). Higher-trophic organisms like birds (Verlis *et al*., 2013) consume plastic waste not just directly but also indirectly through secondary ingestion (Naert *et al*., 2007). Fragment-form microplastics consumed by birds could cause both physical damage (such as inflammation, obstruction, or cellular disintegration in the digestive organs) and chemical toxicity (from plasticizers or chemicals acquired from the surrounding environment) (Rochman, 2015). The fragment type of microplastic accounts for 21% in the sediments of the Kosasthalaiyar River. Tiny microplastics may induce toxicity, act as a new long-term environmental hazard, and impose selective pressure on terrestrial organisms if ingested. Sub-lethal negative consequences, such as growth loss, were reported in earthworms after exposure to 150 µm microplastics in their diet (Lwanga *et al*., 2016). In natural environments, microplastics loaded with pollutants would sink and concentrate in sediments, generating a higher concentration in this compartment and raising the toxicological risk for benthic animals (Bellasi *et al*., 2020). There is a possibility that trophic transfer of MPs via benthic food webs could be a significant pathway for

MP ingestion by predatory benthos, which should be investigated further in future field studies (Fang *et al*., 2018). Unlike marine anthropogenic particles, microscopic artificial debris in terrestrial ecosystems may be seen as a "closer to home" environmental issue, leading to increased public and scientific attention (Rillig, 2012).

CONCLUSION

The primary source of MP contamination in the study area is improper dumping on the shores of the river. The study's findings indicated the need for effective steps to minimise river pollution caused by waste mismanagement in the river. As a result, the consequences will be reduced, safeguarding the world from the pollution's impact. Plastic litter is typically dispersed near roadways, in soils, or in unregulated dumping sites. Residents must be aware of the significance of proper plastic waste disposal as well as the implementation and discussion of plastic waste management policies at all levels of society. Efforts must be made to educate the public about the effects of microplastics on human and environmental health. Because of growing environmental concerns over plastic pollution, policy-making and legislation are vital aspects of protecting the integrity of urban aquatic ecosystems.

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Authors' Contribution

R. Priyanka: Writing-original draft, Field work and sample Collection, Data analysis, Editing, Software and Conceptualization. **Bavani Govindarajulu**: Review and Editing.

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