Presence of Microplastics in Estuarine Environment- A Case Study from Kavvayi and Kumbla Backwaters of Malabar Coast, Kerala, India

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Abstract

Microplastics (MPs) are gaining global attention in recent years due to its widespread distribution and potential health impacts. The present study focuses on the distribution and characterization of microplastics in the sediments and bottom dwelling organisms of Kavvayi and Kumbla backwaters of Northern Malabar region, Kerala, India. MP isolation procedure including density separation, organic matter digestion and membrane filtration followed by visual and spectral analysis using optical microscope and confocal Raman spectroscopy have been utilised for the microplastic evaluation. Microplastics of size range up to 500 nanometres were analysed and presence of MPs were detected in all samples with an average abundance of 99.5 ± 69.43 particles/ kg and 96.57 ± 29.96 particles/ kg in Kavvayi and Kumbla backwaters respectively. Raman spectral analysis confirmed about 50% of MPs to be synthetic elastomers with the remaining half encompassed by PA, PE, PEST, PU and PP. Higher abundance of MPs in the edible aquatic organisms like clams, prawns and fishes confirmed the transfer of MP from the environment into living organisms envisages the need of further investigation on toxicological impacts and management strategies.

1. Introduction

Microplastics (MPs) is the collective name for a wide variety of small synthetic polymer particles derived from plastic debris exposed into the environment which are having a size less than 5000 microns. MP is considered as an emergent contaminant, ubiquitously present across the world from equator to poles and are more prevalent in oceans. Thompson et al. (2004) first demonstrated the occurrence of micrometre sized (< 1mm) microplastics in marine sediments by analysing subtidal, estuarine, and sandy sediments from 18 locations across the UK. Nearly 44 percent of marine MPs are sourced from land (Wang et al. 2016) and rivers play a crucial role in transporting them into the marine environment. River flow into the oceans and estuaries carrying huge amounts of water and sediments along with many pollutants including microplastics (Rech et al. 2014). MPs are found to be a great menace to natural ecosystems (aquatic and terrestrial) and living organisms (vertebrates and invertebrates) in recent years, particularly due to its potential ingestion by marine organisms.

Microplastics may be purposefully manufactured in the form of abrasives, pellets or powder or get derived from large plastic litter by chemical, biological and mechanical forces acting upon them over time. The material characteristics of the plastics like colour, shape, density, partial crystallinity, oxidation resistance, biodegradability, residual monomers, additives, surface properties, all influence the behaviour of microplastics derived from them. The mechanism of degradation can be classified based on causative agents as biodegradation, photo-degradation, thermo-oxidative degradation, thermal degradation and hydrolysis (Andrady 2011). It may also change the properties of the polymers (Wang et al. 2016) resulting in the desorption of toxic chemical additives like phenols, brominated flame retardants, Tris (2 chloroethyl) phosphate, boric acid, heavy metals etc (Hermabessiere et al. 2017; Rezania et al. 2018). Synthetic polymers also act as surfaces of adsorption for many chemical compounds. Toxic chemical pollutants like dichloro diphenyl trichloroethane (DDT), polycyclic aromatic hydrocarbons (PAHs), hexachlorocyclohexane and chlorinated benzenes were found to be highly absorbed by PVC, PE, PP and PS (Avio et al. 2017). Fragmentation increases the abundance and surface area of synthetic particles in the environment which in turn enhances its potential adsorption and the susceptibility of entering into the food web (Reisser et al. 2014). Biological processes within the body of organisms result in further degradation and leaching of toxic chemicals which may be persistent and result in biomagnification. Fate and impacts of microplastics are still not fully identified (Avio et al. 2017), but many chemicals associated with plastics have been identified to have the potential to lead to many adverse conditions such as cancer, impaired reproductivity, decreased immune response, and other malformation in animals and humans (Auta et al. 2017).

Microplastics are of significant importance than the other categories of plastic debris by virtue of its size, making them more prone to enter into the biological compartments of the ecosystem (Alomar et al. 2016). Dispersion of MP particle among sediment and water phases also have serious impact on the intake of these particles by living organisms. The presence and abundance of microplastics in estuarine sediments can be attributed to a variety of reasons, including hydrodynamic pressures, rainfall, sediment kinds, population density, sediment depth, and microbiological activity and estuary region. A study conducted in Tampa Bay showed that heavy rainfall leads to increased microplastic content in the site, likely due to increased discharge from rivers and storm water runoff (McEachern et al. 2019). Microplastics are subject to turbulent transport, settling, aggregation, biofouling, resuspension, and burial, with movement between the water column and sediments, similar to natural colloids and suspended solids (Li et al. 2020; Peng et al. 2017).

The present study aimed at evaluating the microplastic profile of two different estuarine environment, Kavvayi and Kumbla estuaries in Northern Malabar region of Kerala, India, by analysing sediment and living organisms collected from it. It also attempts to identify the prominent sources of microplastic input into respective study area.

2. Materials And Methods

2.1 Study area

Two distinct estuarine systems in the northern Malabar Coast have been considered for the present study: Kavvayi and Kumbla Backwaters.

Kavvayi backwater is a coastal estuarine extended between 12°12'56.5"N, 75°07'03.9"E and 12°02'38.8"N, 75°11'07.2"E in northern Malabar of Kerala. The lagoon is 22.3 km long and stretches from Nileshwar in Kasargod to Ezhimala in Kannur. This lagoon may be as wide as 1754.12 metres and as narrow as 155.81 metres. It also has a maximum depth of 8.9 m and a minimum depth of 0.5 m. Total of five rivers flow into this estuarine system including Kariangode, Kavvayi, Peruvamba, Ramapuram, and Nileshwar. The rivers provide roughly 4351 MCM of yearly discharge to the wetland, with about 94% of that discharge occurring during the monsoon and the remaining 6% occurring solely as non-monsoon flows (Shiji et al. 2015). Map of Kavvayi backwater depicting the sampling sites is given in Fig. 1.

The Kumbla estuary is located about 10 kms north of Kasaragod town in Kerala. The estuary covers an area of 1.7 km^2, lies at 12° 35’47” N latitude and 74°56’29” E longitude. The estuary is formed at the mouth of River Shiriya and a few more trivial rivers in Kasaragod also drain into it. Kumbla harbours a large range of flora and fauna those are inevitable for the livelihood of the residents here. The estuary also contains many types of mangroves and allied plants and attracts a lot of migrant and resident birds, fish and crustaceans. Map of Kumbla with the sampling sites is given in Fig. 2.

2.2 Sample collection and isolation of microplastics

2.2.1 Collection and Treatment of sediment samples

Sediment samples were collected using a Van Veen grab sampler from 12 locations across Kavvayi backwaters and 7 locations across the Kumbla estuary. Three grabs of samples were collected from each site which was then mixed thoroughly and reduced to around 1 kg by quadrating. The samples were collected in glass containers and stored in insulated ice boxes for transporting and further stored in a deep freezer at -22ºC in the laboratory.

All sediment samples were dried in a glass tray covered with aluminium foil in a hot air oven at 50°C until it was completely dried. Dried samples were then thoroughly grinded using motor and pistil to prevent agglomeration of sediment grains (Sruthy & Ramasamy 2017). Duplicates of 300 g of dried samples from each site were then sieved through a series of ASTM sieves (Krishnakumar et al. 2020) with pore sizes of 2 mm, 600 µm, 300 µm, and 150 µm. Density separation and organic matter removal was performed based on the method proposed by National Oceanic and Atmospheric Administration (Mausra and Foster 2015). Sediment fractions from each sieve size were collected followed by density separation with 5 M sodium chloride (NaCl) (300 g/L), solution at a volume of about 3 times that of the sediments. The supernatant collected was subjected to organic matter digestion 20ml 0.05 M Fe (II) solution and equal amount of 30% hydrogen peroxide (H2O2) to digest the possible biogenic organic matter. Samples were then kept in a hot air oven at 50°C for 24 hrs (Mausra and Foster 2015). The sample solutions were finally filtered through 0.45µm pore size nitrocellulose filter membrane using a glass filtration assembly under vacuum. To ensure recovery of all particles the walls of the filtration device and storage bottles should be washed and rinsed with ultrapure water. The filter membranes were stored in clean and labelled petri plates and kept at 40°C for drying.

2.2.2 Collection and Treatment of biological samples

A vertebrate and invertebrate organism was randomly collected from both sites based on the availability at the time of sediment sample collection. Samples were collected using fishing nets with the help of fishermen except for clam samples which were handpicked directly from bottom sediments. Silver bellies/ Pony fish (*Leiognathus sp.*) and Yellow clam (*Meretrix casta*) were collected from Kavvayi estuary while Pearl spot/ Green chromide (*Etroplus suratensis*) and Indian prawns (*Penaeus indicus*) (India Biodiversity portal) were collected from Kumbla estuary. The samples were kept in glass containers and stored in insulated ice boxes for transporting it to the laboratory which was further stored in a deep freezer at -22ºC.

Four individuals of vertebrates (fish) and eight individuals of invertebrates were taken as samples for microplastic analysis. Samples were thawed and thoroughly cleaned using distilled water to remove any externally attached microplastics. Body length and weight of all samples were measured followed by dissection of fish samples to separate respiratory and gastrointestinal tracts (R-GIT). In case of clam samples, soft tissue was separated from the shell using a scalpel. The samples were kept in a 200 ml conical flask, properly sealed with aluminium foil and subjected for drying at 50 ºC in a hot air oven for 24 hours.

Microplastic extraction from living tissue was done following peroxide oxidation method (Ghosh et al. 2021). 50 ml of 0.05 M Fe (II) ($FeSO_4$) solution and 50 ml of Hydrogen peroxide (30%) is added to all samples and shaken thoroughly for 1 min. The reaction began within 3 minutes of mixing with the release of a high amount of heat which lasted for up to 10 minutes. The samples were then kept overnight in an incubator at 50 ºC with intermittent shaking. An additional 10 ml and 20 ml of H_2O_2 with subsequent incubation were required for the complete digestion of R-GIT samples and clam samples respectively. For prawn samples, since the whole individual is considered for the analysis, it required 2 sets of subsequent digestion with 20 ml H_2O_2 followed by density separation with 5 M NaCl. The resulting liquid samples were filtered using 0.45 µm pore size, 47 mm diameter gridded Millipore nitrocellulose membrane under vacuum. Filter papers were further stored in clean glass petri dishes and dried in an incubator at 40ºC.

2.3 Sample analysis and characterization

All the samples containing filter papers were observed under compound light microscope at 40X magnification for the presence of microplastics. Samples were visually analysed for the abundance and morphological characteristics of microplastics, classifying them into five categories: fibre (thin or fibrous, straight plastic particle), fragment (hard, jagged plastic particle), film (a thin plane of flimsy plastic), foam (deforming and pellet/beads (hard, spherical plastic particle).

Polymer characterization of the observed microplastics was carried out using Confocal Raman Spectroscopy (HORIBA LabRAM HR Evolution) with a spectral range of 50-4000 cm-1 and spectral resolution of 0.5 cm-1/pixel. Spectral scans employed 532 nm excitation laser focused by 50X objective and 600gr/mm. Up to three spectra had been obtained for each particle and spectral modifications were accomplished by LabSpec6 data acquisition software (HORIBA). Spectral data obtained were then compared with KnowItAll Informatics System (Bio-Rad Laboratories) polymer reference spectral library.

2.4 Quality control

To prevent potential background contamination during sampling and laboratory processing, a number of precautions were taken. Before each treatment, the glassware was washed thrice using deionized water and covered in clean aluminium foil when not in use. Use of plastic wares was minimalized with the use of glassware wherever possible. To reduce the risk of contamination from synthetic clothing fibres, cotton lab coats and gloves were worn at all times when processing samples. Additionally, during the collection, extraction and analysis, the samples were always wrapped in aluminium foil to prevent air contamination. To eliminate air borne contamination from interfering with the results three blanks were performed. All solutions and reagents used for the sample treatment were pre filtered before being added to the samples. Microscopic examination of the filter papers was conducted prior to filtration to ensure particle free condition.

3. Results And Discussion

3.1 Microplastics in sediment samples

3.1.1 Abundance of MP

Microplastics were found in all sediment samples collected from both Kavvayi and Kumbla backwaters. In Kavvayi, the least number of microplastics were recorded at Site 8 (22.0 ± 5.0 particles/kg) and most number at site 9 (245.5 ± 21.5 particles/kg) with an average abundance of 99.5 ± 69.43 particles per kilogram of sediments. In the case of Kumbla, a mean abundance of 96.57 ± 29.96 particles/kg was observed with highest number at site 1 (134.5 ± 11.5 particles/kg) and least at site 3 (49.5 ± 5.5 particles/kg). There have been reports of microplastics in estuaries with similar geographic profile like Vembanad (Sruthy and Ramasamy 2017) and high abundance of microplastics in tropical estuarine sediments with around 160–1000 items per kg in Guanabara Bay, Brazil (Alves and Figueiredo 2019). Most of the microplastics from both Kavvayi and Kumbla estuaries belonged to the size range of less than 300 µm with only few particles larger than 600 µm, similar to the observation of sediments from Mandovi- Zuari estuary (Gupta et al. 2021). It is controversial to the fact that in most cases, there will be a significant number of larger microplastics (LMP) found in environmental samples (Alves and Figueiredo 2019; Firdaus et al. 2020). This may be due to the fragmentation of larger particles during disaggregation of dried sediment for sieving and further processing. The comparison of the results with the MP studies in estuarine sediments from across the world is given in Table 1.

Table 1
Comparison of the present study with other MP studies on estuarine sediments

Location	Abundance	Polymer type	Reference
Guanabara Bay, Brazil	160 – 100 items/kg	Nylon, PE	Alves et al., 2019
Lioahe Estuary, China	120 ± 46 par/kg	PE, EPR, PET, PP	Xu et al., 2020
Kayamkulam Estuary, India	421.5-438.8 par/kg	PEST, PE, PP	Radhakrishnan et al., 2021
SW Atlantic Argentinean Estuaries, Argentina	1030 ± 657 items /kg	PE, PEST, PVC, PP	Díaz-Jaramillo et al., 2021
Shores of waitemata Harbour, New Zealand	16–380 par/kg	PP, PEST, PE	Hope et al., 2021
Karnaphuli River Estuary, Bangladesh	22.29–59.5 item/kg	PET, PS, PE, Nylon	Rakib et al., 2022
Cochin estuary, India	1340 ± 575.22 par/kg	Cellophane, PS, PE, PP, Nylon	Suresh et al., 2020
Mandovi-Zuari estuary, India	4873–7814 par/kg	PAM, PA, PVP, PVC, PI	Gupta et al., 2021
Jagir Estuary, Indonesia	92–590 par/kg	PEST, PE, PP	Firdaus et al., 2020
Vellar Estuary, India	24.8 ± 0.75 to 43.3 ± 0.98 par/kg	LDPE	Nithin et al., 2022
Kavvayi and Kumbla Estuaries, India	99.5 ± 69.43par/kg 96.57 ± 29.96par/ kg	PB, PI, PU, Nylon, PEST, PP, PE	Present study

Higher abundance of microplastics was mainly recorded at locations near the confluence of rivers into the backwater and at the estuarine mouth. In the case of Kavvayi backwaters, microplastic abundance was highest at site 9, located to the south of Kavvayi Island where the river Peruvamba and river Ramapuram enters the estuarine system. Peruvamba River flows through one of the major townships in Malabar region, Payyanur and the river was reported to be polluted by untreated sewage and agricultural surface runoff (Shiji et al., 2015). Full-fledged quarrying activities are also prevalent in the river basin (KSRRC Report). An anomaly in MP abundance was observed at site 6 with a high value of 186.0 ± 25.45 particles/ Kg, even though it is not located at any river mouth region or an area with high human interventions. It is noteworthy that the sediments at this location had a very fine texture with black colour and active mussel cultivation in its nearby places. The possibility of some drainage outlet may explain the high number of MP. Least number of microplastics were found at site 8 (22.0 ± 5.0 particles/kg) which was located inside the mangrove plantation region. Site 11 located just outside the mangrove region had a MP abundance of 136.5 ± 7.5 particles/ kg showing the influence of mangroves in the dispersion of microplastics in the sediments.

In case of Kumbla backwaters, highest MP abundance was reported at Site 1 which is the mouth of river Shiriya into the estuary and site 7 which is towards the southern end of the estuary with comparatively lesser flow rate. Study area had visible plastic pollution along its bank over the entire strength with larger waste dumps near site 4. Majority of the dumped waste were plastic carry bags and single use bottles along with fishing nets and other equipment.

3.1.2 Morphological characterisation of MP

Considering the morphological characters of microplastics, it can be classified as fiber, fragment, film, foam and pellets (Kershaw et al. 2019, Van Cauwenberghe et al. 2015). Fragments were the most prominent type with around half the number of total particles recovered followed by fibers. Fragments are largely derived from the disintegration of larger plastic debris over time, being a clear indicator of plastic waste mismanagement in the area. Approximately 361.5 and 650 fragment MPs were recovered from the entire sample set from Kumbla and Kavvayi Backwaters respectively. The leading source of fiber microplastics would be the domestic laundry discharge in the area which may be direct or indirect through drainage water and atmospheric fallout. Fishing nets also contribute significantly to the number of fiber MPs. Films were the next prominent type considering its presence in almost all samples collected. These are flat, even surfaced pieces sourced mainly from disintegration of plastic carry bags and synthetic surface coatings (Syakti et al. 2018). This type of particles tends to flow on the surface waters by virtue of its structure hence have lesser abundance in the bottom sediments. Film MPs had a significantly higher proportion in samples of Kumbla with around one out of six MP being a film. This may be justified by the shallowness of the estuary with an average depth of 1.25 metres. Many of the submerged regions rise above water level during low tides, which may owe to the presence of more film MPs in the bottom sediments. Foams are characterized with air cavities which may deform its shape under pressure. This type of MPs has an uneven distribution in both estuaries but have a considerable abundance wherever it is present. Pellets were found only in two sampling sites (site 9 and site 11) of Kavvayi which were totally absent in case of Kumbla. Both these sites are located closer to the Kavvayi Island with active tourism and developmental activities. Site 9 alone has a pellet profusion of 66.0 ± 5.0 particles/kg, which is higher than the total MP count at some sampling sites.

Visual identification through microscope reveals that a notable amount of microplastics were devoid of any colour with around 40–44% MPs from both the study areas seem to be colourless. It includes fragments, fiber, film and pellets. All pellet MPs identified were colourless or in other words transparent solid particles. Among coloured particles, black fragments were the majority followed by black and blue fibers. Foam MPs were seen in white, brownish or blackish mostly due to presence of sediments and other impurities over them. Films appeared in blue, green and white shades with the majority of them being colourless.

3.1.3 Polymer characterization of MP

Polymer characterization and confirmation of microplastics using Confocal Raman spectroscopy reveals 97.5 percent of the suspected particles to be microplastics. About 2 percent remaining include organic matter, cellulose and minerals like muscovite. Polyamides (Nylon), polyisoprene (PI) and polybutadiene (PB) were the most frequent polymers in both Kavvayi and Kumbla backwater sediments which accounts for more than 50 percent of the microplastics identified. The remaining half includes polyurethane (PU), Polyester (PEST) (including Polyethylene terephthalate (PET)), Polystyrene (PS), Polypropylene (PP), Polyethylene (PE) and synthetic resins (Melamine-Formaldehyde, Epoxy).

Polybutadiene and Polyisoprene are synthetic elastomers with widespread applications. Polybutadiene is the principal constituent in the manufacturing of vehicle tires which get frequently disintegrated into microparticles due to abrasions. The PB microplastics appear as black solid fragments and the presence of butadiene styrene copolymer, poly vinyl benzoate, and Acrylonitrile/butadiene/styrene copolymer in these samples confirmed its source as vehicular tires. Polyisoprene has many domestic and medical applications and alsohas an additive role in many products. Polyamides including Nylon 6, Nylon 6, 6 and Nylon 11 were found as colourless or white fibers, film, foam and few fragments. Polyurethane, acrylonitrile/ butadiene styrene copolymer, vinyl chloride/ ethylene, poly (n-butyl acrylate) was also frequently found along with the polyamide containing particles. Fishing gears, nets etc are the prominent source of polyamide microplastics (Saipolbahri et al. 2020). Polyester was all fibers or films, coloured or colourless which also include PET derived from single use plastic bottles. Coloured fragments were mostly either polypropylene or polyethylene and present in a range of colours like different shades of blue, red, brown, orange, yellow and black. They are mainly sources from breakdown of plastic containers and equipment (Turra et al. 2015; Xu et al. 2020) mostly derived from domestic activities. Pellet types of microplastics found in Kavvayi were also found to be Polyethylene spheres. Fendell & Sewell (2009) gives facial cleansers as a source of PE microspheres. Presence of polyurethane and synthetic resins like Epichlorohydrin- Bisphenol A (EBA) and Melamine-Formaldehyde constitute around 10–15 percent of total MPs and have many applications as additives in foams, paints and coatings.

3.2 Microplastics in organisms

Microplastics have been detected in the body of all organisms under study with maximum abundance in the respiratory and gastro-intestinal tract of *Etroplus suratensis* also known as Green chromide (34 ± 12.66 particles/ individual) collected from Kumbla estuary. *Metetrix casta* (Yellow clam) collected from Kavvayi estuary ranked second in the abundance of microplastics with 32.75 ± 5.87 particles/ individual. Details of the sample organisms and microplastic abundance in their body are depicted in Table 2.

Table 2
Abundance of microplastics in living organisms

Sampling site	Organisms	Length	Whole Weight	Weight considered	No. of individual	Particles/ individual
Kavvayi	Meretrix casta	2.562 ± 0.213	6.0.45 ± 1.676	1.266 ± 0.342	8	32.75 ± 5.879
	Leiognathus sp.	5.925 ± 0.457	3.928 ± 0.573	0.153 ± 0.0237	4	15.75 ± 6.994
Kumbla	Penaeus indicus	7.25 ± 0.420	2.059 ± 0.388	2.059 ± 0.388	8	10.75 ± 8.261
	Etroplussuratensis	4.2 ± 0.356	2.28 ± 0.531	0.28 ± 0.077	4	34 ± 12.668

All organisms collected were juveniles making them smaller in size with bottom dwelling habitat in the brackish water environment. Yellow clams (*M. casta*) are benthic organisms found in sandy areas of the estuarine floor while silver bellies are mostly planktivorous with juveniles having benthopelagic habitat. Planktivorous fishes are mostly vulnerable to the accidental consumption of microplastics from the water column (Kalaiselvan et al. 2022). Nylon was the most abundant MP in the respiratory and gastrointestinal tract (R-GIT) of fish from Kavvayi with negligible presence of PE and resin polymers. Up to 12 items of MPs have been detected in 100 g intestine of

Leiognathus species derived from Gulf of Mannar (Selvam et al. 2021) while the current study gives around 15.75 ± 6.994 particle from the R-GIT of a single individual which weighs as less as 0.15 ± 0.023 grams. However, almost all polymers detected in the Kavvayi sediment samples were present in the tissue of clam samples. While in organisms from Kumbla, PB was prominent in both samples but nylons which were frequent in fish samples were totally absent in case of prawns. Polyethylene was found only in the site 6 of Kumbla which was surface sediment sample but present in significant numbers in the R-GIT of pearl spot. Distribution of MP in the body of organisms shows no similar trend to that of the sediment samples. Additionally, it is evident that a higher number of microplastics enter the body of organisms through its surroundings. Fragments and fibers were the most abundant MP type found with a couple of film particles. MPs with all five morphological characters were found only in the yellow clam sample collected from Kavvayi. Around 10 MP particle/100g of muscle tissue was observed for fish (*Leiognathus sp.)* which had up to 12 MP/100g in its intestinal tissue (Selvam et al. 2021). This shows the possible extent of the presence of MP in the muscle tissues of fishes considered for the present study.

The current study evaluated MPs as small as 0.5 µm, hence there are higher chances of MPs getting absorbed into the body from the digestive tract leading to bioaccumulation. It has been reported that the river Shiriya has been polluted with chemical organic compounds like Endosulfan (Solomon 2011), and MP can act as potential vectors of higher concentration of these chemicals into the body of organisms. Pearl spot being an endemic species in brackish water of the region and an important part of the local cuisine are a matter of concern with the high abundance of MP in its body. MP abundance (34 ± 12.66 par/ individual) in E. suratensisis comparable to studies on the same species from Vembanad with 13 ± 5 number /individual (Nikki et al. 2021). Toxicological study conducted on *E. suratensis* using PVC (Polyvinyl chloride) microplastics recorded significant changes in growth, behavioral and enzymatic activities (Vijayaraghavan et al. 2022).

The study provides an overall microplastic profile from across the entire stretch of both estuarine systems inclusive of all morphological and basic chemical characters. Comparatively lesser number of organisms has been considered for the MP evaluation in the current study which can be the notable drawback of the results presented. It was primarily due to onsite attempts to collect small sized individuals under the same conditions as sediment sample collection and also due to seasonal fluctuations in the availability. Influence of the mangroves on the dispersion of microplastics in the estuaries is also not well discussed currently. Further studies can be done on large scale analysis of the commercially important aquatic organisms for microplastics and their possible transit into the body of higher organisms like birds, humans and other mammals depending on these wetlands.

4. Conclusion

Researches on emerging pollutants like microplastics have been increasing in recent years due to the rising eco-toxicological concerns. The present study provided a report on the microplastic profile of sediments and living organisms from two different estuaries in Malabar region of Kerala. The sites, Kavvayi and Kumbla backwaters being different in their size and activity level shows no significant difference in the overall microplastic concentration. It reveals the extent to which the MPs enter the biological system and the possibility of being transferred. The study also attempted to identify the possible sources of microplastic release into the environment envisaging the need for new methods and techniques to prevent the possible microplastic input.

Declarations

Ethical Approval: Not applicable

Consent to Participate: Not applicable

Consent to Publish: Not applicable

Authors Contributions: All authors contributed to the study conception and design. Material preparation, data collection and analysis were performed by Aiswriya V Padmachandran, N. Sreethu and Fathima Nasrin I. The first draft of the manuscript was written by Aiswriya V Padmachandran. Reviewing, editing and work supervision was carried out by Anbazhagi Muthukumar and Muthukumar Muthuchamy.

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Tables

Table 1. Comparison of the present study with other MP studies on estuarine sediments

Location	Abundance	Polymer type	Reference
Guanabara Bay, Brazil	160-100 items/kg	Nylon, PE	Alves et al., 2019
Lioahe Estuary, China	120 ± 46 par/kg	PE, EPR, PET, PP	Xu et al., 2020
Kayamkulam Estuary, India	421.5-438.8 par/kg	PEST, PE, PP	Radhakrishnan et al., 2021
SW Atlantic Argentinean Estuaries, Argentina	1030 ± 657 items /kg	PE, PEST, PVC, PP	Díaz-Jaramillo et al., 2021
Shores of waitemata Harbour, New Zealand	16-380 par/kg	PP, PEST, PE	Hope et al., 2021
Karnaphuli River Estuary, Bangladesh	22.29-59.5 item/kg	PET, PS, PE, Nylon	Rakib et al., 2022
Cochin estuary, India	1340 ± 575.22 par/kg	Cellophane, PS, PE, PP, Nylon	Suresh et al., 2020
Mandovi-Zuari estuary, India	4873-7814 par/kg	PAM, PA, PVP, PVC, PI	Gupta et al., 2021
Jagir Estuary, Indonesia	92- 590 par/kg	PEST, PE, PP	Firdaus et al., 2020
Vellar Estuary, India	24.8 ± 0.75 to 43.3 ± 0.98 par/kg	LDPE	Nithin et al., 2022
Kavvayi and Kumbla Estuaries, India	99.5 ± 69.43par/kg 96.57±29.96par/ kg	PB, PI, PU, Nylon, PEST, PP, PE	Present study

Table 2. Abundance of microplastics in living organisms

Sampling site	Organisms	Length	Whole Weight	Weight considered	No. of individual	Particles/ individual
Kavvayi	Meretrix casta	2.562±0.213	6.0.45±1.676	1.266±0.342	8	32.75±5.879
	Leiognathus sp.	5.925±0.457	3.928±0.573	0.153±0.0237	4	15.75±6.994
Kumbla	Penaeus indicus	7.25±0.420	2.059±0.388	2.059±0.388	8	10.75±8.261
	Etroplussuratensis	4.2±0.356	2.28±0.531	0.28±0.077	4	34 ± 12.668

Figures

Figure 1

Map of Kavvayi Backwater showing sampling sites

Figure 2

Map of Kumbla Backwater showing sampling sites

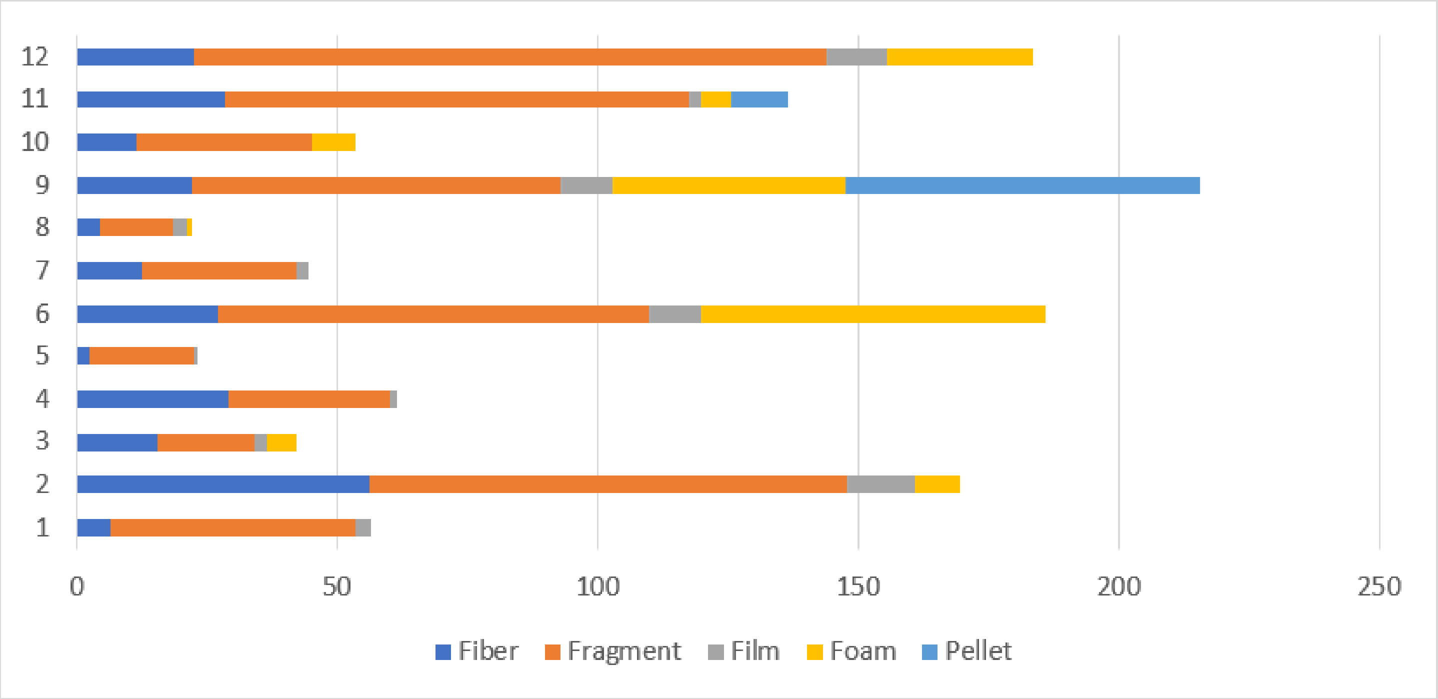

Figure 3

Morphological distribution of MP from sediments of Kavvayi Backwaters

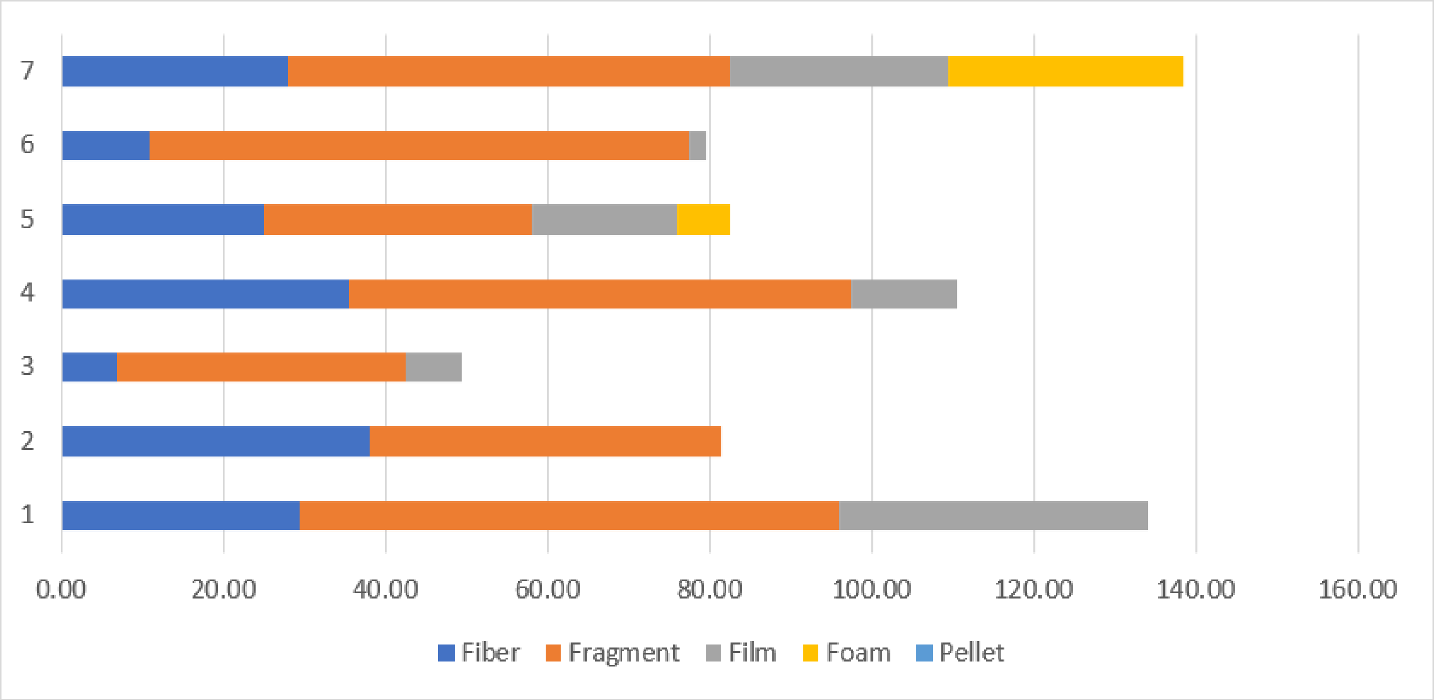

Figure 4

Morphological distribution of MP from sediments of Kumbla Backwaters

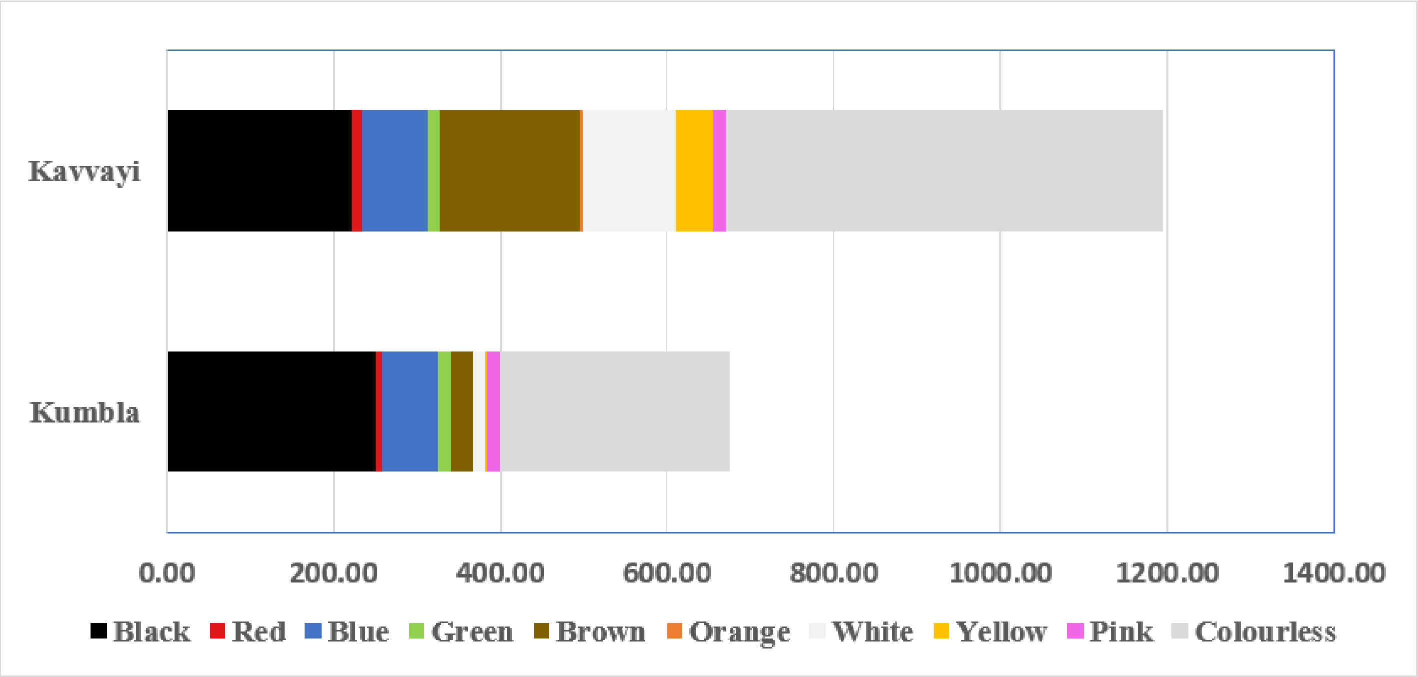

Figure 5

Distribution of MP in Kavvayi and Kumbla backwaters based on colour

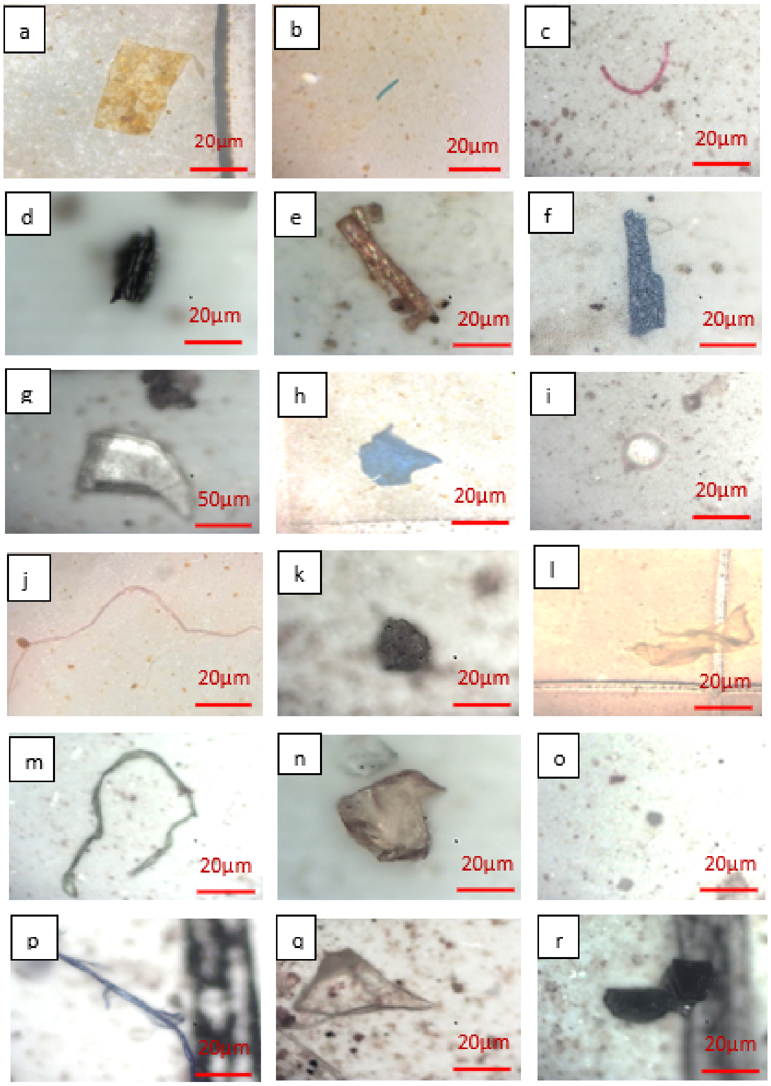

Figure 6

Different microplastic particles identified based on polymer type: Polyester (a, b), Polypropylene(c,d,e), Polyethylene (f, g, h, i), Polyamides(j, k, l), Resins (m, n), Polystyrene (o), Polyurethane (p), Polyisoprene (q) Polybutadiene (r).

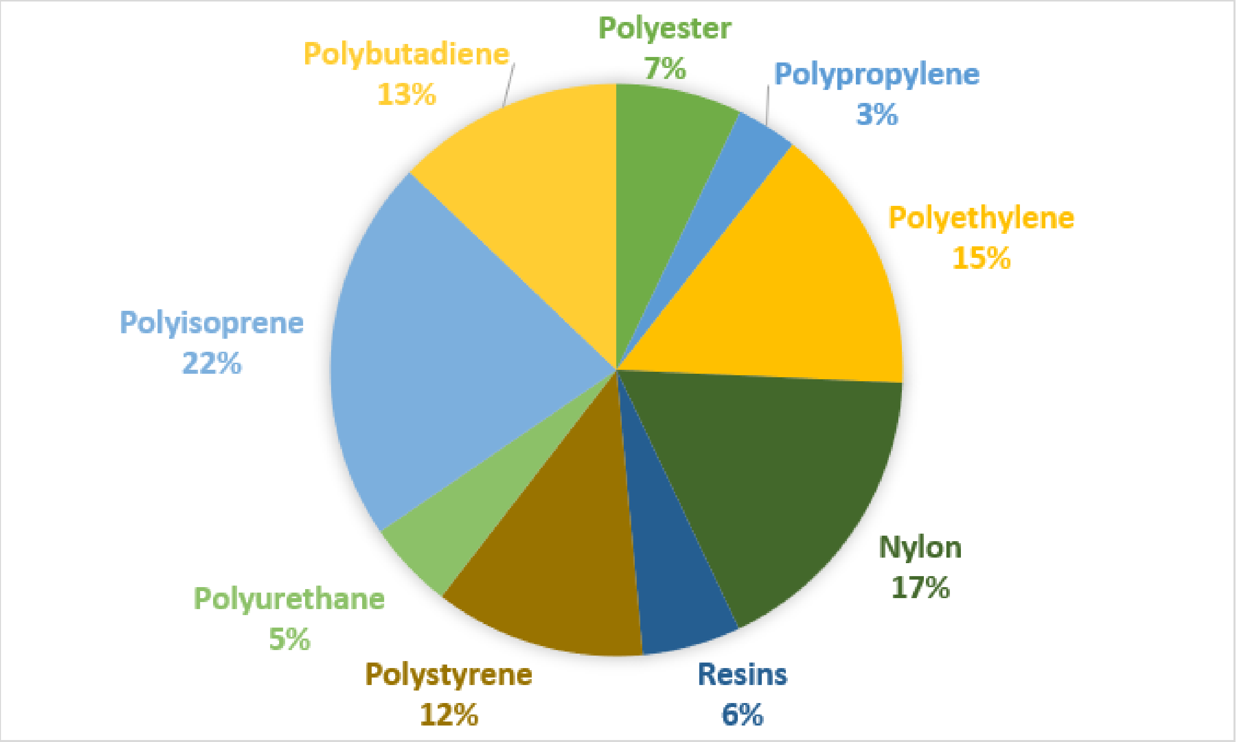

Figure 7

Polymer characterization of MP of sediments from Kavvayi Backwaters

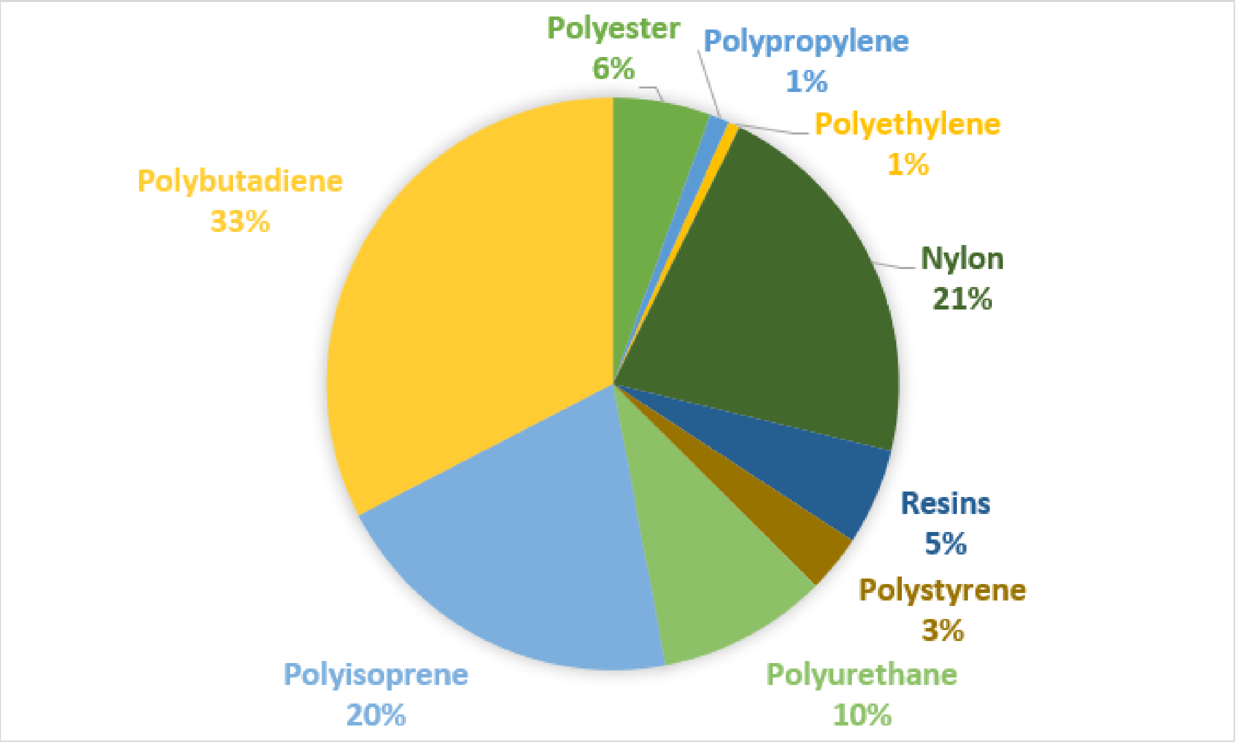

Figure 8

Polymer characterization of MP in sediments from Kumbla Backwaters