RESEARCH ARTICLE

The Impact of Microplastic Contamination on the Coastal Environment of Chennai

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Abstract: Microplastic contamination in the Chennai coastal region is a growing concern due to the intake of abandoned garbage from various sources. This study aimed to assess the extent of microplastic contamination by analyzing microplastic trash collected from 25 spots along the Tamil Nadu coast, spanning a distance of 1076 kilometers. The results revealed that microplastic contamination was more prevalent during higher wave conditions compared to lower tides. Shorelines near riverbanks exhibited significantly higher quantities of microplastics than those affected by fisheries and tourist activities. The main types of microplastics found were polyethylene, polypropylene, and polystyrene, with plastic shards comprising the majority of the trash (47-50%). Furthermore, analyses of fish species collected from shore regions showed that 10.1% of the fishes had consumed plastic particles. This emphasizes the potential risk of microplastics entering the marine food chain. The study highlights the need for microplastic filtering from estuaries, coastline waters, and other potential sources. In conclusion, microplastic contamination poses a serious hazard to the Chennai coastal region. Urgent measures are required to mitigate and reduce microplastic pollution, particularly near river openings, to protect the marine ecosystem and the food chain. Efforts should focus on preventing the entry of microplastics into the environment and promoting sustainable waste management practices to safeguard the coastal ecosystem.

Keywords: Coastline trash, micro plastic, marine environment, aquatic ecosystem, fourier transform infrared spectroscopy

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1 Introduction

Due to its numerous advantages and inexpensive price, plastics are utilized extensively in a variety of industries in daily life. The manufacturing of plastics worldwide nearly topped 360 million metric tonnes in 2018. However, prolonged use of these polymers in combination with negligent or reckless behaviour has resulted in a deposition of plastic in the oceans (Andrady, 2011). Only around 18% of the plastic produced gets recycled due to poor disposal practises, which result in discharged polymers being in the environment for several hundred years in either their original form or shattered form. Particle fragmentation results from the breakdown of the plastic surface on a physical, biological, and photochemical level (Apitz et al., 2009; Somasundaram and Radhakrishnan, 2023). Microplastics are described as particles between 0.001 and 6mm in size (Ashwini and Varghese, 2020). Because of their diameter, a range of animal types can swallow these particles (Barnes et al., 2009). Although translocation, bioaccumulation, and trophic accumulation are still under investigation, they may be detrimental to these organisms (Secco et al., 2005). Because it has been shown that the coast is where the majority of lost plastic eventually ends up, the issue of microplastics along the shore is one that is becoming more and more of a worry worldwide. It comes as a result of the increased contribution of waste disposal from various sources. However, it has been determined that land-based activities are the primary causes of the marine microplastics contamination (Förstner, 2004). There are several ways that land-based polymeric particles might enter aquatic habitats, for as through poor microplastics removal in traditional WWTPs storm water systems, runoff from roads (Umar et al., 2019). The atmospheric fallout of microplastics caused by wind transportation is also thought to have a substantial role in the spread of microplastics in the environment (Claessens et al., 2011). Undoubtedly, there is more to learn about this subject. The analysis of microplastic dispersion through time and space, as well as the distribution of factors including polymer type, size, and form in various coastal environments around the globe, is urgently needed. India's coastline stretches for more than 7,500 kilometres (Collignon et al., 2012). Due to the various contexts of its multiple shores, it is hard to replicate the factors generating the microplastic contamination at these seashores. Although microplastic pollution is a site-specific phenomenon, it can be understood by taking a look at the pathways for contaminants that have already been identified by prior research. Studies on the microplastic pollution of Indian beaches, however, are lacking. There haven't been many research done in India up to this point. These studies demonstrate how negatively microplastics can impact the marine environment. Microplastics pollution has recently created new research difficulties that are obviously interconnected and require a multidisciplinary perspective. As a result, credible and comparable data must be produced using procedures that have been proven and are trustworthy. In the Adyar and Cooum Estuaries near Chennai, this study describes a method for assessing the amount and distribution of microplastics in the sediments and marine water. The prevalence and distribution of microplastic particles were investigated in this study. The existence and dispersion of micro - plastics in coastline sediment and seawater were investigated utilizing FTIR (Sillero, 2011). The objective of the study is to assess the microplastic extraction from the source samples and analyse the chemical composition and concentration variation spatially and temporally.

2 Materials and Methods

2.1 Study area

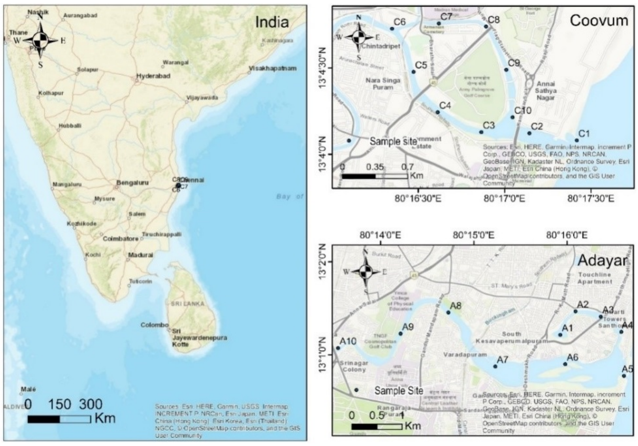

Figure 1. Index map of the study area.

Chennai's Adyar and Cooum Estuaries served as the survey's locations. Seawater and sediments were extracted from 20 study site (Figure 1) inside the Adyar and Cooum rivers, respectively (Kole et al., 2017). Testing was conducted between August 2019 and October 2020 to examine the amount and dispersion of micro - plastics at every testing location. The Coromandel Coast of the Bay of Bengal is home to Chennai, the capital of the Indian state of Tamil Nadu. It's one of India's metropolises and has a greater than 19 km-long stretch of land. Among the three rivers that flow through the metropolis are the Adyar and the Cooum. In both places, a 2km stretch was chosen for this field study. The Chembarambakkam Lake in the Kanchipuram district is the source of the 42-kilometer long and 860 Sq. Kms drainage basins Riverbed Adyar, which joins the Bay of Bengal at the Adyar coastline. The river Cooum is one of the shortest streams flowing into the Bay of Bengal, with a basin range of 290 sq. km and a length of 72 km. Its source is the Cooum reservoir in the Thiruvallur taluk. It virtually splits the city in half as it travels from west to east (Liu et al., 2019). Over 40,000 hut-dwelling households could find a home along the shoreline. In these rivers, the vast majority of the city's trash is dumped. Thermal power plants, leather ternaries, the tire and gasoline industry, fishery harbors, and other sources all release a lot of garbage. As a result, a sizable amount of domestic and industrial pollutants is transported along the shore by these streams. The second-longest urban seashore on earth, Marina Beach stretches 6 kilometres between both the Adyar and Cooum riverbanks. South of the Adyar estuary is Eliot Beach. Because of the increasing popularity of various coastlines are weekend getaway spots, a majority of non-biodegradable rubbish is dumped there. Although the shoreline of Chennai had been intensively studied over the years and numerous research had already been conducted to tackle the consequences that substantial human activity has had on this ecosystem, there is little information available on the presence of micro plastics.

2.2 Sample collection and preparation

For sea water sampling, a neuston plankton net with a net pore size of 153 micrometers (m) was used. The net pore size refers to the diameter of the openings in the net, which determines the size range of particles that can be captured during sampling. In this case, the net pore size of 153 m indicates that particles larger than or equal to this size were collected for analysis. It was towed behind each station for 30 minutes at a velocity of between three and five knot to obtain water specimens (Moore, 2008). During lab testing, the particles inside the net and the net tubes were rinsed into a transparent jar. To eliminate the larger particles, freshwater specimens was first cleaned utilizing a 32 m strainer. To remove the reduced microplastics when the mixture became too thick, saturated sodium chloride solutions were injected. The samples were finally dried at 50°C, purified using glass fibre filtering papers, and put in Petri trays (Ng and Obbard, 2006).

For collection of sediments Ekman Grab, prior analytical examination, the items were freeze dried. Utilizing sodium iodide, a high-density solvent, the reduced microplastics were extracted from the silt by allowing them to rise to the top. Utilizing a solution of 30% hydrogen peroxide, the final phase of processing involves oxidation. The solution was shaken, then permitted to rest a day before being strained by glass fibre filter paper. Under a magnifying glass, the particles remained on the filtering paper were clearly classified as micro plastics if they lacked cellular or organic morphological characteristics, were not glossy, had a constant width, respectively (Ojeda et al., 2009). Forceps were used to remove the nanoparticles that were determined to be micro plastics.

Fish samples are collected around the sampling points. The fish samples are operated to get gills and digestive tract extracted. Then these parts are carefully inserted into the mixture of nitric acid and sulphuric acid which dissolved all the organic matters and leave microplastic content remaining (Simon et al., 2019).

The chemical composition of microplastic obtained from each samples using a Shimadzu Fourier Transform Infrared Spectroscopy with Attenuated Total Reflectance diamond crystal mounts, the polymeric compositions of microplastic particles were identified. These absorbance spectra were recorded at a resolution of 5 /cm and 75 /cm added scans in the infrared range of 5000-500 /cm. Different types of polymeric materials were found, depending on the frequency of covalent bonds found in samples. The type of polymers was identified by comparing the samples' Infrared spectra with this specific Shimadzu reference library dataset (Karthik et al., 2018).

2.3 Sampling of microplastics from beach sediments

A wide range of land uses and activities, such as conurbation-dominated beaches, agricultural land, tourist destinations, fishing grounds, and ecologically sensitive places, were included in the selection of sampling locations (Sruthy and Ramasamy, 2017). A range of criteria, including urban and rural areas, tourist destinations with a rich cultural heritage, fishing ports, and ecologically vulnerable places, were used to choose the sampling locations. Beach sediments were gathered in Cooum and Adyar (Unice et al., 2013). The coastline regions' climate effects are mainly impacted by a variety of regionally specific factors, including stream flow, tourist, and fisheries. Furthermore, the ecosystem in general is impacted by anthropogenic processes along the beaches as well as site-specific population impact actions (Cooper and Corcoran, 2010). One of these is the vast amount of land-based plastic debris that beaches near river mouths acquire and that is dispersed by coastal currents, tidal/wind movement, and other factors (Elkhatib and Oyanedel-Craver, 2020). Conversely, beaches with fishing and tourism are the main non-point sources of microplastic pollution and frequently encounter direct littering. Furthermore, Tamil Nadu's entire shoreline was split into four geographical sections that ran from north to south based on human activity along the shores and in the adjacent areas (Karthik et al., 2018). Using a global positioning system, the geographic coordinates of each site were logged for use in the GIS platform. Tamil Nadu's river banks and beaches are being periodically cleared of solid garbage with the help of regional local administrations, non-governmental organisations, and a few operated by commercial companies (both industrial and household) (Koelmans et al., 2019).

In contrast to the rural areas of the coast, where unstructured garbage removal by rag pickers is more prevalent, organized waste management is conducted in the urban areas of the study region Chennai. However, a considerable portion of the plastic trash that ends up on beaches and coastal seas cannot be removed by traditional management measures. Only a small percentage of the overall waste gathered from beaches is treated (recycled), and the majority is dumped in landfills and open pits. Samples of microplastics were taken from the beaches along the High Tide Line and Low Tide Line (Cashman et al., 2020). A 15 L stainless steel container was filled with beach sediments that were scooped up from a 1x1 m quadrat at a depth of around 5 cm. Sediment samples were taken from two quadrats at each location, one from HTL and one from LTL, and stored in pre-cleaned 15 L containers until sieve analysis. 10 L of seawater that had been filtered to remove microplastic (0.48 m Whatman glass fibre) and concentrated with Sodium chloride (120 g/l) were used for each sample, and the mixture was agitated for 10 minutes. In order to separate different size fractions of microplastics (e.g., 0.3-0.6; 0.6-1.18; 1.18-2.36 and 2.36-4.75 mm) and microplastics with size range between 4.75 and 9.5 mm, the supernatant was wet sieved. The job was done inside a positive air pressure laminar flow hood to prevent any external contamination (Han et al., 2019). The sieves were gently scrubbed with a natural fibre brush and veterinary detergent, and then thoroughly rinsed with Milli-Q water in between each new sample. In order to check for contamination at this stage of processing, 20 ml of Milli-Q water was also put through the sieves and filtered using a mesh disc. Under a microscope, a careful examination was performed at the start and end of this process to ensure that all particles had been completely removed from the mesh disc and filter paper. To avoid any fibre contamination, all clothes was covered throughout the procedure, and laboratory cotton jackets were worn. In order to break up and eliminate any adhesive particles, the samples were also rinsed with distilled water before sifting (Van Cauwenberghe et al., 2013).

2.4 Micro plastics chemical constituents

Plastics are synthetic polymers made from different artificial chemical compounds, each of which has special qualities. Although not all of the papers that were assessed conducted in-depth chemical research, they all identified the chemical structure of micro - plastics. The papers being evaluated contained polystyrene, polyethylene, and polypropylene most frequently (Table 1). Several methods have been used to identify plastic particles materials. In the study, infrared (IR) spectroscopic identification was used. This method allows the comparison of the IR spectrum of an unknown plastic sample with the frequencies of well polymeric (Cincinelli et al., 2017). Infrared spectrophotometer, Fourier transform infrared spectroscopy (FT-IR), and near-infrared spectrometer were the many forms of spectroscopy used for microplastics identification. These methods can be used to identify a variety of common polymers, including PP, PE, and polyester. Raman spectroscopy, another type of chemical study, can be used to learn more about the polymer's crystalline structure

(Primpke et al., 2018). In one investigation, temperature was administered simultaneously to a reference material and an unknown sample using a differential scanning calorimeter. Utilizing distinctive fumes from burning and solvents analysis, the polymers that make up microplastics have also been identified. Additionally, particle density and, to a lesser extent, other characteristics like colour can be used to identify synthetic polymers. The density-based identification method was applied in two studies (Corami et al., 2020).

An experiment involved submerging a sample in distilled water, followed by titrations of ethanol, concentrated calcium or strontium chloride solutions, or a mixture of the two, until the polymer fragment was impartially buoyancy. Because these traits have been documented for virgin pellets, using specific features like density and colour seems like a promising way to quickly and economically identify the polymer in plastic pellets. However, this method cannot be used for plastic fragments since their shape and colour are more varied and unlikely to be connected to a particular polymer type. With decreasing particle size, the risk of mistakenly classifying microparticles of unknown origin as microplastics rises significantly. Because it can accurately ascertain the chemical composition of unidentified plastic pieces, the use of spectroscopy is strongly advised for small plastic fragments. This procedure is essential because up to 80% of fragments that FT-IR spectroscopy suggests are microplastics are actually not plastic. It might also be simpler to find microplastics with irregular shapes that cannot be recognised by FT-IR spectroscopy using complementary spectroscopy methodologies, such as attenuated total reflectance FT-IR spectroscopy. However, the key drawback of this instrument is its expensive price. Table 1 displays the Identified Polymer Type and Specific Densities of the Different Polymer Types among the Sorted Microplastic Debris (Hendrickson et al., 2018).

Table 1. Composition of Polymer density and its types (Hendrickson et al., 2018)

Polymer class	Polymer density (g/cm³)
Polyurethane	1.8
Polymethyl acrylate	1.20-1.50
Acrylic	1.11-1.98
Polyvinyl alcohol	1.25-1.66
Polyester	1.68-2.5
Polyamide	1.50-2.07
Polyoximethylene	1.55-1.89
Polyethylene	0.965-0.987
Polyvinylchloride	1.78-1.88
Polystyrene	2.04-2.1
Alkyd	1.68-2.50
Polyethylene terephthalate	1.47-1.55
Polypropylene	1.9-0.95

Standardized sample and specimen handling techniques are necessary for a thorough investigation of long-term patterns. The relevance of consistent operating principles to increase the compatibility of previous and current research in coastal and sedimentary aquatic ecosystems is highlighted by this assessment of methods used in research on micro plastics in the marine ecosystem. To effectively capture the whole size range of marine micro plastics, each of these processes includes sieving of bulk or volume-reduced samples as well as a required visual sorting phase. To ascertain the movements of micro - plastics within aquatic habitats, a layered collection technique should be used for ocean floor sedimentary.

3 Results and Discussion

The results of microplastic concentration in Adyar and Coovum are summarized in Table 2. The mean microplastic concentration in coastal seawater for August 2019 and August 2020 was found to be 741.1 and 518.65 number per litre, respectively. Similarly, marine sediments exhibited mean microplastic concentrations of 164.25, 115.05, 90.65, and 63.55 numbers per kilogram for August 2019 and August 2020. Fish specimens analysed in August 2019 and 2020 showed mean microplastic concentrations of 90.65 and 63.55 numbers per specimen, respectively. Among the sampling points, A6 in Adyar estuary and C5 in Coovum estuary had the highest concentrations of microplastics across all types and variants, while A2 and C1 had the lowest microplastic concentrations.

Table 2. Total Microplastic concentration in Adyar and Coovum sample sites

Sample ID	Coastal water (mg/L)		Marine sediment (mg/kg)		Fish (mg/g)	
	August 2019	August 2020	August 2019	August 2020	August 2019	August 2020
A1	387	278	64	44	45	33
A2	353	250	66	45	42	29
A3	475	339	73	50	55	39
A4	588	415	80	56	67	47
A5	906	620	215	160	113	78
A6	1292	880	289	200	158	108
A7	865	611	200	140	106	75
A8	901	651	209	150	111	80
A9	607	425	178	129	79	56
A10	582	413	113	79	70	49
C1	344	247	92	59	44	31
C2	482	337	99	68	58	41
C3	831	583	192	122	103	71
C4	1172	820	250	165	142	99
C5	1588	1110	304	208	190	132
C6	1089	761	227	169	131	93
C7	780	500	201	150	99	65
C8	693	488	182	127	87	62
C9	501	369	151	110	65	48
C10	386	276	100	70	48	35

Spatially, in both Adyar and Coovum, the microplastic concentrations initially increased and peaked in the middle stream, gradually decreasing near the mouth. This pattern can be attributed to the accumulation of microplastics from urban discharges, which increases as the river water velocity declines upon mixing with seawater. Consequently, the microplastic stagnation becomes highest, leading to an increase in concentration. Further movement of microplastics is restricted towards the mouth, resulting in a steady decline in concentration.

Temporal analysis revealed that in 2019, there was a higher abundance of microplastics due to extensive improper discharge of plastic waste through sewage and municipal solid waste. However, in 2020, the COVID-19 lockdown resulted in a gradual reduction in plastic consumption, leading to a significant decrease in microplastic levels across all categories and sampling locations.

There were no significant differences in microplastic concentration variance between coastal seawater, marine sediments, and fish specimens. The patterns and ratios of microplastics were similar in all categories, indicating an equal distribution within the ecosystem. Fourier Transform Infrared Spectroscopy (FTIR) test results (Figure 2) revealed the presence of major chemical constituents such as polyethylene and polypropylene in the extracted microplastics. The higher presence of polyethylene suggests the presence of degraded plastic covers and plastic materials consumed by humans in daily activities, while polypropylene, although present to a lesser extent, likely originates from long-term plastic products used in households.

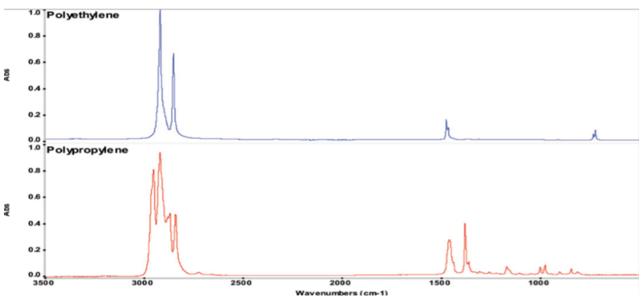

Figure 2. FTIR analysis for the extracted microplastic.

These findings provide valuable insights into the distribution and composition of microplastics in the study area, highlighting the need for effective measures to reduce plastic waste and mitigate microplastic pollution in coastal environments.

3.1 Strategies for environmental restoration and sustainable management

Despite some attempts to improve the aesthetic quality of the streams, the climate along the waterways has continued to deteriorate, primarily as a result of the area's growing population, intrusion on the riverbanks, and sewage discharge. The Cooum drainage finally receives uncleared excrement from clean areas, processed sewage from sewage treatment facilities to the unique CMWSSB in Koyambedu, sludges from commercially established effluent originating from demolished slums, and wastewater from the waste treatment plant. The Cooum River is connected to the Buckingham Channel, which receives treated sewage from the Kodungaiyur Sewage Treatment Plant. Cooum River lacks a regular flow, like other municipal sewers, and is contaminated by the discharge of sewage treatment plants from anti-modern sources. Approximately 532 metric tons of trash are allowed to enter the freshwater transmission base, and the CMWSSB water treatment centre treats more trash than all that.In Chennai, strategic management actions for protecting the maritime environment and sewage treatment can help:

• All infractions must be removed from the Cooum River Bank in order to restore the rivers' integrity, and waste should not be discharged openly. To get rid of ooze, the rivers can also be dug up and de-iced. After a rainstorm, the body of water can be cleaned using rainwater. This loop will guarantee that the flow is restored in the desired way.

• Strict adherence to the rules and authorization from the administration to use high-tech treatment methods for family unit, business foundations, and venture effluents and sewage Practice reliable waterfront boarding as well.

• Offices and foundation in the port to donate,

• Regulate and prevent the unchecked growth of the automated and mechanised pontoon armada, which is to blame for the release of hydrocarbon and pollution into the ocean.

• To prevent remote ocean mining, protect the ocean's depths, and protect the rich variety of marine life's vegetation.

• Must refrain from participating in radiation complex experiments because they endanger the shoreline and coral reefs.

• To draw the public's attention, information must be presented through teaching people how to protect the environment, stop a dangerous atmospheric deterioration, and obtain practical fishing and harbour training.

• Reducing the human population and providing employment to communities who depend on beachfront jobs.

3.2 Different administration methodologies for micro plastic contamination

When addressing microplastic contamination, various administration methodologies can be considered. Here are some different approaches:

• Legislative Actions: Governments can implement strict regulations and policies to control the production, use, and disposal of plastics. This includes measures such as banning or restricting single-use plastics, promoting eco-friendly alternatives, and enforcing proper waste management practices.

• Public Awareness and Education: Raising awareness among the general public about the impacts of microplastic contamination is crucial. Educational campaigns can inform individuals about the sources of microplastics, their effects on the environment and human health, and provide guidance on reducing plastic waste and proper disposal.

• Sustainable Waste Management: Improving waste management systems is vital for reducing microplastic pollution. This includes establishing efficient recycling programs, promoting waste segregation at source, supporting the development of recycling infrastructure, and encouraging responsible waste disposal practices.

• Innovative Filtration Technologies: Implementing advanced filtration technologies at wastewater treatment plants and stormwater drains can help capture and remove microplastics before they enter water bodies. This can involve the use of filters, screens, and settling tanks designed specifically to trap microplastic particles.

• Environmental Monitoring: Regular monitoring programs can be established to assess the levels of microplastic contamination in different environments. This data can help identify hotspots, track trends, and evaluate the effectiveness of mitigation measures over time.

• Collaboration and Research: Collaboration between scientific researchers, government bodies, industries, and NGOs are crucial for developing effective strategies. Funding research initiatives on microplastic pollution, its sources, and potential solutions can lead to innovative technologies and informed decision-making.

• Industry Responsibility: Encouraging industries to adopt sustainable practices and reduce the use of plastic materials is essential. This can involve implementing extended producer responsibility (EPR) programs, promoting eco-design principles, and supporting the development of alternative materials with lower environmental impact.

• International Cooperation: Microplastic contamination is a global issue that requires international cooperation. Governments can work together to establish international standards, share best practices, and coordinate efforts to address microplastic pollution in a comprehensive manner.

Combining several administrative strategies has the potential to result in significant advancements towards reducing the quantity of microplastic pollution and conserving our ecosystems. This might be accomplished by reducing the amount of microplastic pollution.

4 Conclusion

In conclusion, the study highlights the increasing concern over microplastic contamination near the coastline, driven by the intake of abandoned garbage from various sources. The evaluation of microplastic trash collected from 25 spots along the Tamil Nadu coast provided important insights. The findings revealed that microplastics were more prevalent in seaside specimen collections during higher wave conditions, compared to lower tides. Moreover, shoreline areas near riverbanks exhibited a significantly higher quantity of microplastics compared to coastlines affected by fisheries and tourist activities. Plastic shards were found to be the most dominant component of the overall trash, followed by line/fibers and foamy materials. The three main types of microplastics identified through Fourier Transform Infrared Spectroscopy (FTIR) were polyethylene, polypropylene, and polystyrene. Significantly, the analysis of intestinal contents in selected fish species from shore regions showed that 10.1% of the fish had consumed plastic particles. This underscores the potential risk of microplastics entering the marine food cycle and highlights the need for action. The study concludes by emphasizing the urgent necessity for microplastic filtering from estuaries, coastline waters, and other potential sources. It also highlights the potential severe hazard posed by microplastic accumulation in the maritime ecosystem, particularly near stream openings, due to its propensity to contaminate the marine food cycle. Overall, these findings call for immediate measures to mitigate microplastic pollution, protect the coastal environment, and safeguard the health of marine ecosystems and organisms. Based on the findings of the study on microplastic contamination in the Chennai coastal region, several avenues for future work can be explored:

• Long-term Monitoring: Conducting long-term monitoring of microplastic contamination in the Chennai coastal region would provide valuable data on temporal trends and variations in contamination levels. This would help in understanding the effectiveness of mitigation measures and evaluating the impact of changing environmental factors.

• Source Identification: Investigating the specific sources of microplastics in the coastal area would be crucial for developing targeted strategies to reduce contamination. This could involve tracing the origin of microplastics through tracking studies or employing advanced analytical techniques to identify unique markers or characteristics associated with different sources.

• Ecological Impact Assessment: Assessing the ecological impact of microplastic contamination on marine organisms and the overall ecosystem is essential. Future research can focus on studying the physiological, behavioral, and reproductive effects of microplastic ingestion on various marine species, as well as investigating potential trophic transfer and biomagnification of microplastics through the food chain.

• Mitigation Strategies: Developing and implementing effective mitigation strategies to reduce microplastic contamination in the coastal region is crucial. Future work can explore innovative techniques such as the implementation of advanced filtration systems, sustainable waste management practices, and public awareness campaigns to minimize plastic waste generation and improve waste disposal practices.

• Policy Interventions: Advocacy for policy interventions at local, regional, and national levels is necessary to address microplastic pollution effectively. Future research can focus on providing evidence-based recommendations to policymakers, highlighting the urgency of regulatory measures, and promoting the adoption of policies that target the reduction, recycling, and proper disposal of plastic waste.

• Stakeholder Engagement: Engaging stakeholders, including local communities, industries, and government agencies, is essential for effective microplastic pollution management.

Future work can involve collaboration with stakeholders to raise awareness, promote behavioral changes, and develop partnerships for implementing sustainable practices and initiatives.

By pursuing these future research directions, we can further our understanding of microplastic contamination, devise effective strategies for prevention and mitigation, and work towards preserving the coastal ecosystem and safeguarding marine life.

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Author Contributions

Ramesh Somasundaram conducted the experiments and analysed the results. Also, the manuscript draft is composed by Ramesh Somasundaram. Nagalakshmi Radhakrishnan fine tuned the manuscript and guided through the experiments and analysis.

Conflict of Interest

The authors declare no competing interests.

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