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The Prevalence of Microplastics in Water and Sediment Collected from Vellar Estuary in South India

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

A growing global environmental concern, microplastic contamination is a threat to marine environments and may have negative effects on the environment, society, economy, and human health. The current study's goal was to assess the level of microplastic pollution in Tamil Nadu's Vellar Estuary environment. Two sampling sites along the river area were selected to collect sediment and water samples. The types of microplastics were determined and categorized using FTIR, size and the colour. Abundances of microplastics in surface water and sediments were in the ranges of 0–20 items m^{-3} and 10–60 items kg^{-1} dry weight, respectively. Microplastics were more abundant in the sediment compared to that of surface water collected from the respective station in

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the Vellar estuary. Most particles (> 50%) were < 1 mm in the longest dimension; 60% were transparent, pale white and black. Of the 4 compositions identified, polyethylene, polypropylene, and Poly amide are predominated in both phases. The assessment of water and sediment samples from the estuarine environment in terms of microplastic contamination was done for the first time in this study. In light of the quantity of microplastics found in sediments, more investigation is needed to determine the quantity of microplastics discharged by wastewater and other potential emission sources, as well as to assess their role in microplastic contamination of water, sediment, and soil. Future research on microplastic contamination in the sediment of rural areas surrounding the Vellar estuary can build on the foundation this study provides.

Keywords: Sediment; water samples; microplastics; Vellar estuary.

1. INTRODUCTION

"In coastal communities, the mismanagement of plastic waste results in an estimated annual input of 4.8 to 12.7 million metric tons of plastic to the world's oceans" (Jambeck et al., 2015). "Currently, plastic waste is the most abundant ocean contaminant, constituting 80 to 85 % of marine debris" (Auta et al., 2017). "This plastic waste can be classified by size and includes macroplastic (>20 mm), mesoplastic (5–20 mm), and microplastic (MPs) (<5 mm)" (Barnes et al., 2009). "The majority of plastic particles (92.4 %) in the ocean are MPs" (Eriksen et al., 2014). "MPs are considered contaminants of emerging concern (CECs) because they occupy the same size fraction as the plankton and sediments in aquatic habitats, making them bioavailable to a wide range of organisms" (Stapleton and Hai, 2023; Thilagam et al., 2024a; Thilagam et al., 2024b).

"At present, it is generally believed that MPs pollution is a threat to the global ecological environment" (Rochman and Hoellein, 2020; Leela et al., 2024). Therefore, a series of studies were carried out to investigate MPs pollution in marine environments, such as seafloor sediments (Abel et al., 2021), various seawater depths and different coastal locations (Chen et al., 2021; Janardhanam et al., 2022). "While MPs have been quantified in coastal surface waters and sediments worldwide, high variability in abundance is observed within and among studies. In addition, the majority of MPs surveys to date consist of single sampling events and do not quantify spatial and temporal variability as potential confounding factors in the interpretation of their results" (Pojar et al., 2021). "On a large scale, some of this variability can be influenced by geographic differences in urbanization and land use, and seasonal changes in precipitation and hydrology" (Tsang et al., 2020). However, few studies have investigated microplastic variability on smaller spatial and temporal scales, such as daily changes in microplastic abundance within a single sample site.

Following our previous study on microplastics accumulation in the commercial fish collected from Vellar estuary, this study was short time scale on quantifying the abundance of MPs in surface water and sediments. The study also analyzed changes in MPs abundance and particle composition. Quantifying short term microplastic variability and determining the physical drivers impacting variability is important for accurately assessing the level of microplastic contamination at a given site. This information is crucial for designing comprehensive sampling surveys in coastal environments worldwide, optimizing sampling methods, and for properly evaluating risk to coastal ecosystem health.

2. MATERIALS AND METHODS

2.1 Sample Collection and Preparation

Sediment and water samples from two different station viz. station A (opposite to CAS marine biology) and station B (near the mouth of the estuary). The samples were taken from the Vellar estuary at a depth of 1-2 meters along the estuarine area using a boat that was drawn horizontally for 15 minutes at a speed of 2-3 knots and fitted with a trawl net (mesh size: 300 μm; opening dimensions: 30 × 15 cm). A digital flow-meter was installed across the net's mouth to measure the amount of seawater that was filtered. For the purpose of collecting all plastic debris into the collection bag, the net was carefully cleaned with filtered seawater at the end of each sampling. Stainless steel forceps were used to remove the coarse non-plastic items (different organic or inorganic materials) straight after sampling, and glass bottles were used to hold the possible microplastics. MPs abundances are reported as particles per cubic metre (particle/m^3), and sieve analysis of microplastic size classes was performed using dense seawater solution as described below in the sediment processing section (Shim and Thomposon (2015).

The size fraction sieving method and quadrat were used for collecting beach sediments, as explained by Karthik et al. (2018). Sediment samples were collected from multiple points within a 1x1 m quadrat using a stainless-steel scoop, down to a depth of 5 cm from the sediment surface. Until sieve analysis, every sample was kept in 15 L stainless steel containers that had been previously cleaned. A 10-liter container was filled with pre-filtered seawater and swirled for ten minutes to facilitate the separation of microplastic size fractions through subsequent filtration or sedimentation (Karthik et al., 2018). The supernatant was wet sieved right after the procedure. In order to help remove and disintegrate adhesive particles, samples were cleaned with distilled water. Between each sample analysis, Milli-Q water was used to properly rinse the sieves. For additional examination, isolated microplastics were put on a glass petri dish and let to dry in the shade.

2.2 Identification of Microplastics with FTIR

MPs are visually identifiable before the type of polymer is determined. To determine the type of plastic material, Fourier Transform Infrared Spectroscopy (FTIR) is employed. These methods rely on the unique functional groups present in polymer particles and their energy transmission. A Bruker ALPHA FT-IR spectrometer fitted with a single reflection diamond Attenuated Total Reflectance (ATR) attachment was used to collect the infrared spectra. A predetermined weight of around 1 g was applied to a sample that was placed immediately on the IRE in order to guarantee full contact with the diamond ATR. Twenty-four scans were averaged at a resolution of 4 cm^{-1} within the wave number range of 4000 to 400 cm^{-1} in order to record the averaged spectra for each sample. The components found in the transmittance data were labelled after each spectrum was examined using the analytical procedure. Additionally, the data has been compared with earlier research publications.

2.3 Statistical Analysis

Statistical analyses were done using Microsoft Excel. The results were given as mean ± standard deviation." One-way analysis of variance (ANOVA) was performed to determine whether the treatments differed significantly across sampling sites."

3. RESULTS AND DISCUSSION

The present study is the first report of microplastic abundance in sediment and water from the Vellar estuary. In our previous study we reported that microplastics accumulation in commercial fish collected from the Vellar estuary (Dinakaran et al., 2024). A total of 435 and 195 microplastic particles were enumerated from sediment and water samples respectively (Fig. 1). Its abundance ranged between 1 and 7 particles/m^3 with an average of 2.4 and 5.4 at station A and B. The results of MPs abundance in water collected from station A and at station B were given in Fig. 1.

The mean distribution profiles of microplastics in sediment and water collected from different station in Vellar estuary are presented in Fig. 2. The highest number collected from the sediment comparable to the water sample taken from the same station. The microplastics in the sediment were 3 to 4 times that of water in both stations. The abundance of microplastic particles in sediment ranged between 34 and 56 particles/m^2 with highest abundance recorded at station B and the lowest at station A. The mean microplastic abundance at the two stations (50 particles/m^2) is higher than the values reported for Malta in the Central Mediterranean (30 particles/m^2)." The two stations' mean microplastic abundance (50 particles/m^2) is higher than that recorded for Malta, the Central Mediterranean (30/m^2) (Turner and Holmes, 2011), and the Portuguese coast (25/m^2) (Martins and Sobral, 2011) and comparable to the other estuarine region of Tamil Nadu (45 particles/m^2) (Karthik et al., 2018) and the northern Gulf of Mexico (50/m^2) (Wessel et al., 2016).

The sediments of Easter Island, Chile (800/m^2) (Hidalgo-Ruz and Thiel, 2013) and Winyah Bay, USA (200/m^2) have been found to have higher microplastic distributions (Gray et al., 2018). This implies that due to their significantly lower specific gravity, a significant portion of land-based microplastics (originating from the tourism, food processing, mining, and chemical industries in addition to household solid waste) are probably carried onshore by surface residual currents and winds. Furthermore, during the monsoon season, particle movement forced southward by the longshore current will be responsible for the greater abundance of microplastics in the southern sector.

FTIR analysis shows considerable variations in polymer types among samples collected from sediment and water. Polyethylene (PE) and polypropylene (PP) was found to be the most representative plastic types in beach sediment and coastal waters (Fig. 3). The global use of PE as a packaging material (Plastics Europe, 2018) explains its dominance in our sampling sites, and it is in line with earlier environmental surveys carried out in various aquatic ecosystems. The next most prevalent form of plastic that was discovered in coastal waters and beach debris was PP. Because plastic additives leach and bioaccumulate in this coastal environment, the significant abundance of PE fibres in the sediment and coastal waters indicates a high toxicity potential. Furthermore, PE's high rate of PCB and PAH sorption will put tertiary consumers at further risk of biomagnification.

The strong existence of polyamide (PA) and polystyrene (PS) in beach sediments indicated possible influences of large deposition of nylon materials from the fishing nets, and other extensive fishing activities. Relative abundance of these high density polymers was significantly lower ($p < 0.01$) in the total microplastics found in coastal waters than that present in the beach sediments. Conversely, fugitive losses from abrasive blasting of ship and boat hulls and ballast water tanks may have been linked to the much larger contribution of alkyd resins and the existence of copolymer resins in coastal waters (Malli et al., 2023). This suggested that benthic species are more at risk from excessively dense PA materials with negative buoyancy in coastal waters than are marine fish. Microplastics with lower densities, such as PP (0.9–0.91 g/cm^3) and PE (0.92–0.97 g/cm^3), were more prevalent in all water samples. Potential sources of those PP and PS components could include household sewage from residential areas along the river and large fishing companies.

As expected, the microplastics in the size range of 0.2– 1mm contributed significantly to the total plastic composition (Fig. 4). As plastic debris of varying sizes enter the marine environment, breakdown processes such as ultraviolet irradiation, high temperature and mechanical shear forces degrade plastics into smaller particles with size <100 µm (Erni-Cassola et al., 2017). Analysis of the microplastic composition is important as it provides useful information on individual particles, which can be traced back to their sources in most cases. Among the plastics particles collected transparent particles, pale white, blue and black color dominant in both the stations. Color like red and yellow were limited in both stations (Figs. 5 and 6).

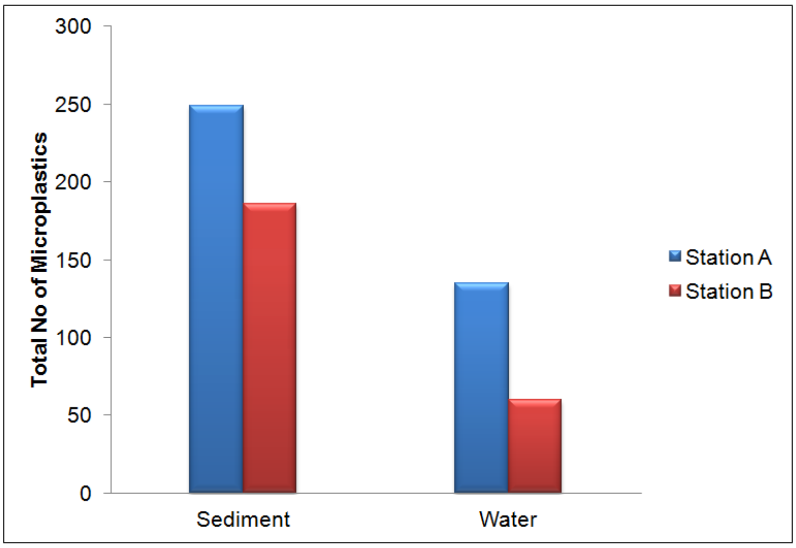

Fig. 1. The total number of microplastics in sediment and water collected from two stations at the Vellar estuary

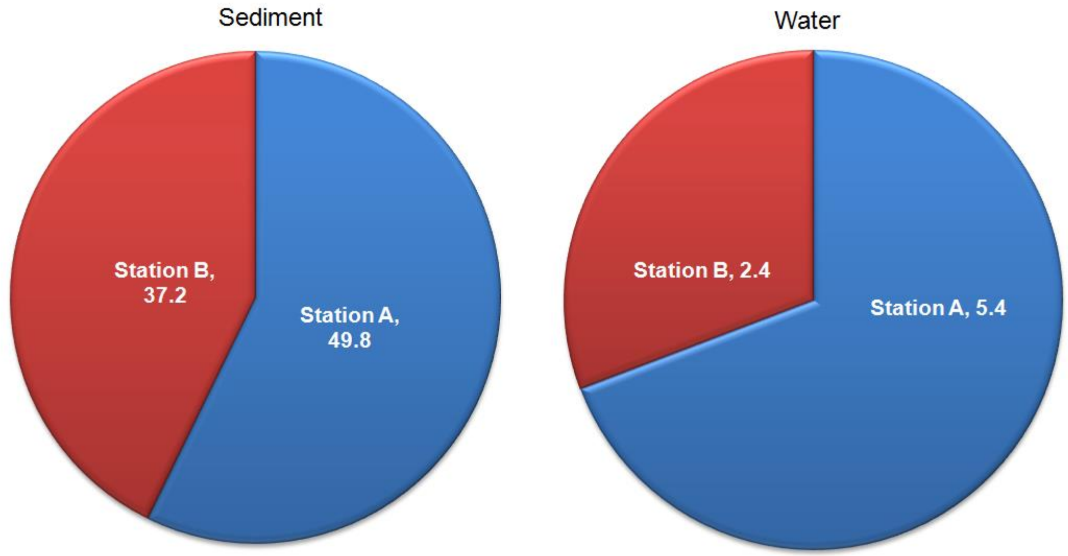

Fig. 2. Average microplastics prevalence in sediment and water collected from two stations at Vellar estuary

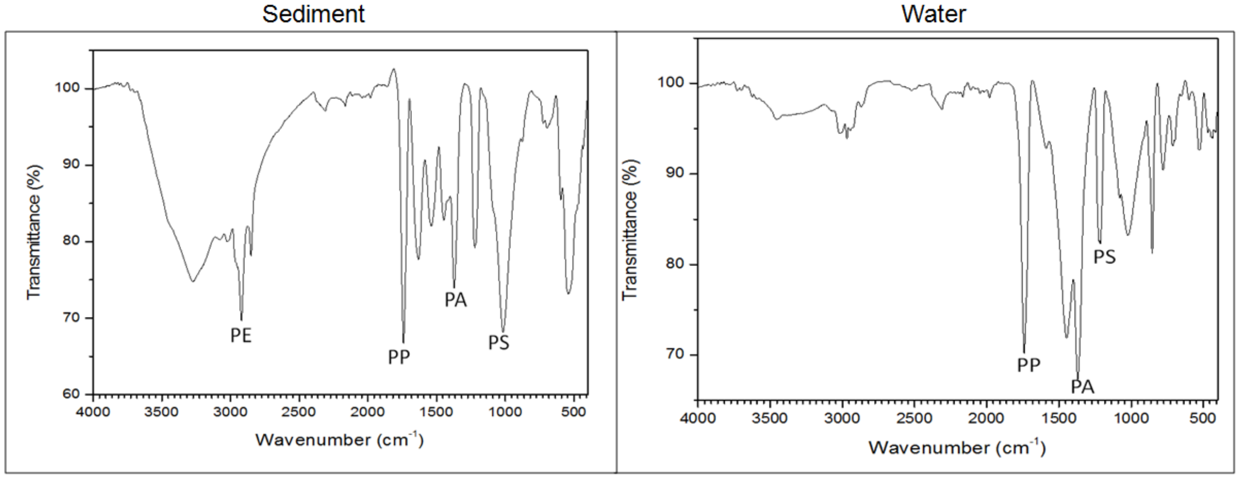

Fig. 3. FTIR for different types of Microplastics in the sediment and water samples collected from two stations at Vellar estuary

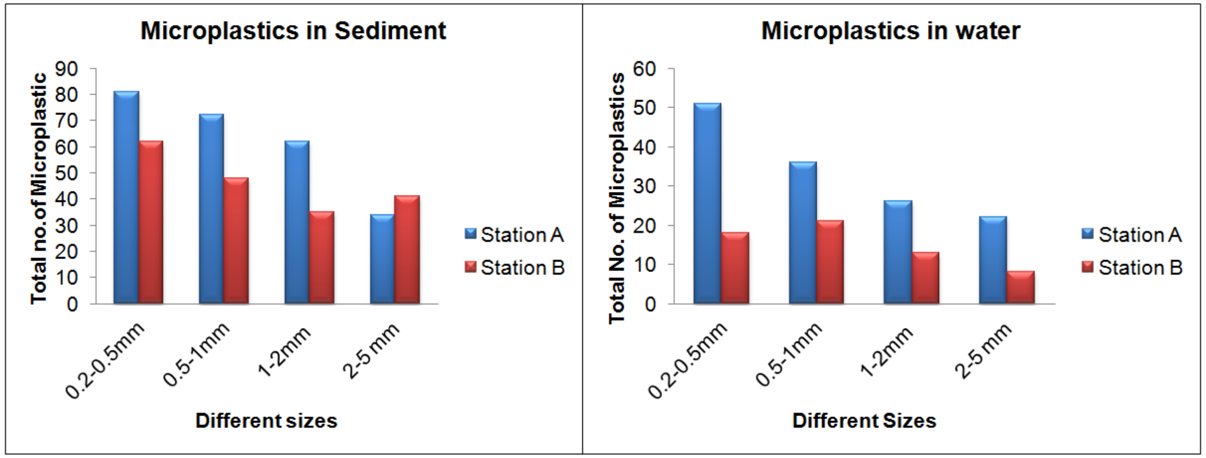

Fig. 4. Total number of Microplastics categorized based on their sizes in sediment and water collected from two stations at Vellar estuary

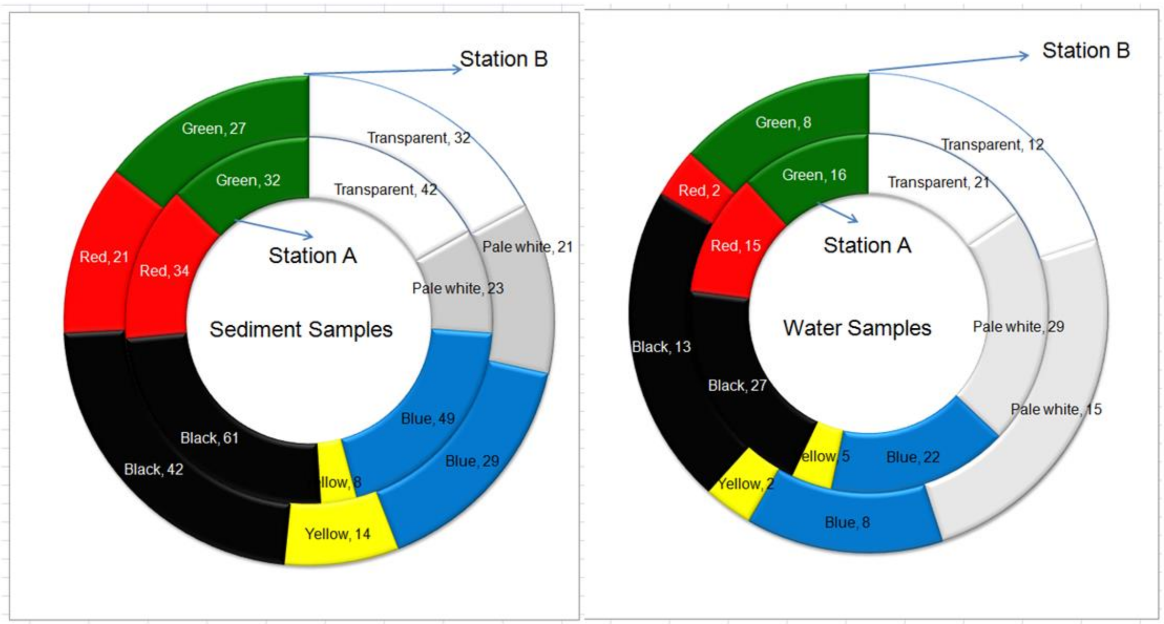

Fig. 5. Total number of Microplastics categorized based on their colour in sediment and water collected from two stations at Vellar estuary

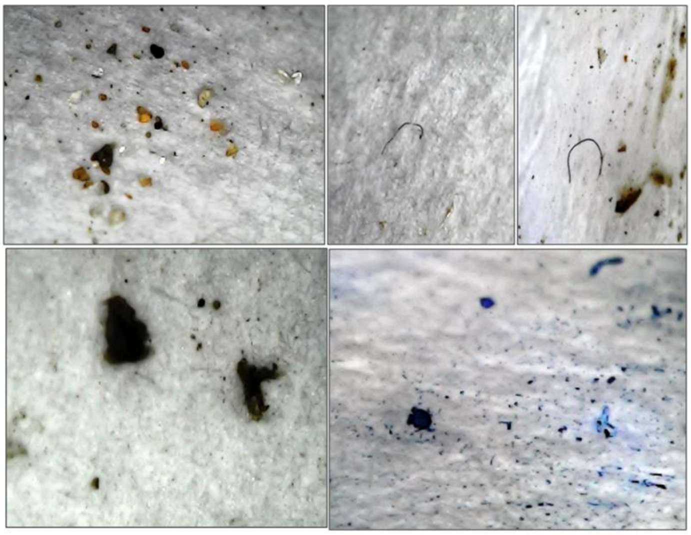

Fig. 6. Microplastics separated based on their sizes and color in sediment and water collected from two stations at Vellar estuary

High concentrations of microplastics in surface waters and beach sediments have frequently been associated with the vicinity of urban areas and river runoff. Furthermore, monsoonal flood discharge from the watershed rivers to the shore that runs through the Vellar estuary is the cause of the high abundance of microplastics in stations A and B. Conversely, because of the low population density and little industrial activity, the beaches near station B have the lowest quantities of microplastics. The bulk of microplastics can be eliminated from municipal waste by sewage treatment plants, however untreated sewage from nearby rural non-point sources may be dumped into the coast, polluting the marine environment. Large amounts of plastic waste, especially single-use plastics like Polyethylene terephthalate bottles, styrofoam food wrappers/containers, carry bags, straws and plastic tea cups, are contributed by the area's small-scale vendors, hotels and houseboats, as well as the high volume of tourists visiting the area. This leads to beach littering.

4. CONCLUSIONS

The regional differences in the quantity, size, colour, and structure of microplastics found in the sediments taken from the Vellar Estuary and coastal waters are reported in this study. The findings demonstrated that sediments and coastal waters had the highest mean abundance of microplastics, respectively. Based on FTIR-ATR analysis, the two most prevalent polymers among the various types of microplastics found in beach sediments and coastal waters were PE and PP. Determining the potential effects of microplastics in coastal ecosystems requires immediate attention, particularly with regard to their physical and chemical transformation and subsequent trophic transmission into the benthic and pelagic food web. These insights will aid in the creation of more effective laws on the use of additives, strategies for the selective use of plastics, and the adoption of environmentally friendly activities. Additionally, our earlier work showed that several marine species especially commercially valuable pelagic fish are impacted by plastic contamination. Furthermore, to comprehend the connection between MPs and their ecotoxicological risks to the food chain across coastal habitats during various seasons, further sampling and research are needed.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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