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Microplastic footprints in the seawaters of Chinnamuttom Coast, Kanyakumari: An investigation

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Abstract

The study examines the microplastics contamination in marine waters along the Chinnamuttom coast. Density separation, filtration and sieving methods are employed to collect microplastics. The morphology, shape and colour of the microplastics collected were determined through visual analysis using microscopic identification. Microplastics were characterized using Scanning Electron Microscopy (SEM) and FT-Raman spectroscopic investigations. The study revealed the presence of microplastics smaller than 5 mm. Approximately 70 mg of dried microplastics were obtained per 5 liters of water. The microplastics primarily consisted of fibers, pellets, and fragments, exhibiting a range of colours including orange pellets, black filaments and fibers in blue, pink, white and purple hues. Particles as small as 20 µm in diameter were detected using scanning electron microscopy, while Raman spectroscopy identified polymers such as polystyrene and nylon through their distinctive vibrational peaks, confirming the presence of bonds like C-H, aldehyde and C=C. The extensive pollution underscores critical ecological issues facing the Chinnamuttom coastal environment, potentially intensified by nearby fishing and tourism practices. The results emphasize the critical necessity for approaches aimed at reducing microplastic contamination in these aquatic environments to safeguard marine biodiversity and the overall health of ecosystems.

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Introduction

Microplastics are defined as plastic fragments or particles that measure less than 5 mm in diameter, resulting from the breakdown of larger plastic materials (Pellini *et al.*, 2018).

Microplastics are widespread in the environment, particularly in marine settings, as a result of hydrodynamic processes and transportation via wind and ocean currents. Large ocean gyres such as the Pacific, Atlantic, and Indian Oceans, along with polar regions and the equator, host them, stretching from coastal areas to the open seas (Galgani *et al.*, 2013). Microplastics are characterized by a variety of morphologies, including foils, foams, fibers, granules, fragments, and microbeads (Klein *et al.*, 2018).

Microplastics can be classified into two categories based on their original dimensions. Municipal effluent could directly introduce industrially produced particulates and powders, originally designed as plastic microbeads, into the ocean as primary microplastics (Cole *et al.*, 2011). Various physical, biological, and chemical processes fragment and degrade substantial plastic pieces, resulting in smaller particles known as secondary microplastics that may enter marine ecosystems (Arias-Villamizar *et al.*, 2018).

Secondary microplastics refer to the fragmentation of larger plastic materials resulting from various forms of degradation, including biological processes involving microbial species, photodegradation caused by solar ultraviolet radiation, and mechanical abrasion due to wave action. Mechanical damage, photodegradation, and oxidative degradation are all mechanisms that degrade fragile polymers into microplastics in the ocean (Wagner *et al.*, 2014).

A diverse array of sources contributes to microplastic pollution in the marine environment, broadly classified as inland-based, sea-based, and air-based (Andrady, 2011; Browne *et al.*, 2011). According to Lebreton *et al.* (2017), rivers are the most critical conduits for the transportation of microplastics from inland regions to the ocean. The terrestrial environment is the source of approximately 80% of the plastic debris in the ocean (Andrady, 2011; Mani *et al.*, 2015). Rivers transport plastic debris from urban drainage systems and sewage effluents to the sea, while coastal tourists immediately dispose of their plastic garbage in the environment (Andrady, 2011). Marine sources come from fisheries, maritime transport, and offshore industry (Bell *et al.*, 2017). Plastic debris may end up in the waterways due to broken or lost fishing or aquaculture gear (Law and Thompson, 2014).

Due to their increased bioavailability and potential negative effects on marine ecosystems over the long term, microplastics are expected to garner significant public attention in the next few years (Velzeboer *et al.*, 2014). Although the exact nature of microplastics (MPs) and the harm they do to marine life is still largely unknown, there is mounting evidence that these contaminants pose a serious threat to marine ecosystems (Chen *et al.*, 2017). Measures and initiatives are necessary to address the issues arising from microplastics and enhance plastic waste management. Hence, the present study aims to classify the microplastics based on their shape, size, colour and to evaluate the chemical composition of microplastics found in the seawater of the Chinnamuttom coast.

Materials and methods

Study area

Chinnamuttom is a coastal village located 200 meters (660 feet) above sea level in latitude 8.094345°N and longitude 77.561445°E. There are more than 15,000 people living there. Notably, Chinnamuttom is the sole coastal location on the Eastern Coastal Plains, despite the fact that the coastal sections of Kanyakumari District are normally located near the meeting point of the Western and Eastern Coastal Plains. The coastal area has black sand and is rich in minerals. Chinnamuttom receives a lot of rain during the monsoon season— roughly 1,465 millimeters (57.7 inches) on average per year. Here, the temperature ranges from 20 to 35°C (68 to 95°F). In this area, the best fishing season runs from June through March. To safeguard fish during their reproductive season, fishing vessels are not allowed to venture into the sea in April and May (Fig. 1).

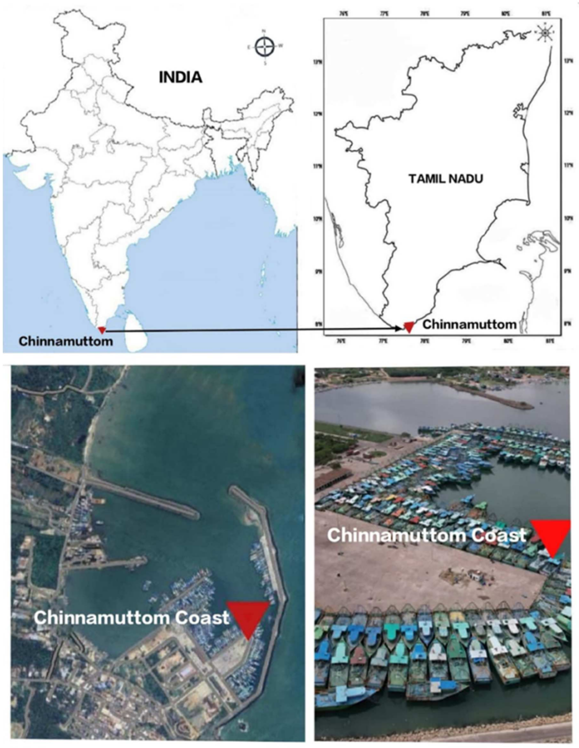

Fig. 1. Map showing the location of Chinnamuttom coast

Analysis of microplastics

The analysis of microplastics typically involves several methods and materials for sampling, extraction and identification.

Sampling procedure

Five litres of water sample were collected from the Chinnamuttom coast in plastic bottles to distinguish, recognize, and describe the microplastic in the provided seawater sample. Sieving, density separation, and filtration are three categories under which separation techniques can be grouped.

Preparation of the collected sample

Isolation of microplastic by sieving method

The first step in sample preparation is a visual sorting process to remove any visible microplastic particles larger than 5 mm. Following this, the isolation of microplastics from the provided seawater sample was executed using a sieving technique. Five litres of seawater passed through a 5 mm metal sieve to exclude larger microplastics and retain particles less than 5 mm in size. Subsequently, the sieved water sample was subjected to a density separation process for further analysis.

Isolation of microplastics by density separation method

The collected sieved sample was centrifuged at 3000 rpm for 10 minutes to separate high- and low-density particles. After the centrifugation, the supernatant and pellet were collected. The pellet was washed thoroughly with distilled water to remove the salt content. After that, the collected pellet was dried in a hot air oven at 40°C. The dried pellet was viewed under an inverted light microscope for microplastic contents, and the collected supernatant sample was used for further filtration.

Isolation of micro plastics by filtration method

The microplastics were separated using the filtration method. The collected supernatant sample was filtered using a sterile membrane filtration apparatus equipped with cellulose nitrate membrane filters of 0.2 µm pore size. A suction pump was used to facilitate this process. Following filtration, the filter paper was thoroughly rinsed with distilled water to prevent the formation of salt crystals on the dried filters. The particles retained on the filter paper, along with the filter itself, were placed in a petri dish and dried in a hot air oven set at 40°C. The dried filter paper was subsequently examined for the presence of microplastics under an inverted light microscope and weighed to determine the mass of microplastics, paving the way for further analyses.

Light microscopic observation

The dried filter was taken for microscopic study, which observes at 10X magnification. Physical methods were firstly applied for fast characterization, and photomicrographs were taken. The suspected particles were analyzed with SEM and FT-Raman spectroscopy for further analysis.

Sample preparation in SEM analysis

After the filtration, the microplastics collected on the filter paper were subjected to SEM analysis. A certain portion of filter paper was loaded on a stub provided for SEM analysis. The stub is made of copper; in the shape of a small cylinder about the size of 1 mm in diameter, one side of the stub was stuck with double-sided carbon material.

After loading the sample on the carbon material, the stub was fixed to a holder. The holder accommodates about 4 samples at a time for 10 minutes twice, and then they were collected for further characterization. The images of microplastics were obtained in the scanning electron microscope (FEI-Quanta FEG 200F Secondary Electron Microscope, Indian Institute of Technology, Chennai).

Identification of microplastics in FT-Raman spectroscopy

Raman spectroscopy is based on Raman effective measurement of the wavelength and intensity of inelastically scattered light from molecules or crystal lattices. The energies of molecular vibrations shift the wavelengths of scattered light from the incident light. Polystyrene and naphthalene standards are regularly used for testing signal-to-noise ratio and wavenumber accuracy.

Results and discussion

Isolation of microplastics by sieving method

Microplastics are often characterized as plastic particles measuring less than a certain upper size threshold (<5 mm) (Razeghi and Hamidian, 2021). Water samples from Chinnamuttom are subjected to filtration using a fine metal mesh to extract microplastics measuring under 5 mm. The results showed the presence of microplastics measuring less than 5 mm, suggesting that the larger plastic waste had previously broken down into these smaller pieces. The findings of Gordon *et al.* (2022) indicate that sieving techniques are primarily effective in identifying smaller microplastics. During the sampling procedure, larger particles either fragment or escape detection.

The presence of these tiny plastic particles poses significant ecological risks as they become available to a wider range of marine organisms, such as plankton and fish larvae. Studies show that smaller microplastics are more easily absorbed, which may lead to accumulation throughout the food chain and impact the feeding behaviour, development, and reproduction of marine organisms (Wright and Kelly, 2017).

Isolation of microplastics by density separation method

A widely utilized method for isolating microplastics from water samples involves density separation. This method distinguishes microplastics in the Chinnamuttom water samples based on their density; low-density microplastics are extracted in the supernatant, whereas high-density microplastics are obtained as a pellet.

Andrady (2011) states that microplastics often exhibit heterogeneity, as their densities can vary based on the specific type of polymer from which they are composed. The density of microplastics influences their distribution within a water column. Low-density microplastics, such as polyethylene and polypropylene (PE and PP), remain suspended, whereas those with higher density tend to settle at the bottom, posing risks to benthic ecosystems (Sul and Costa, 2014).

Isolation of microplastics by filtration Method

The extraction of microplastics from the supernatant involves a filtration process, resulting in an approximate yield of 70 mg of dried microplastic particles in 5 liters of water samples (70 mg/5 lit).

Visual analysis

Microplastics are often classified according to their size, shape (fibers, pieces, beads, films, and foams), colour and morphology (Melo-Agustín *et al.*, 2022). Microscopic identification showed the occurrence of microplastics such as fibers, pellets and fragments in the Chinnamuttom water sample analysis. The composition consists of 55% fibers, 30% pellets, and 15% fragments, as depicted in figure 2. Microplastics identified in the Chinnamuttom water samples include orange pellets, pink fiber, white fibers, fragments, blue fibers, nylon fibers and purple fiber (Fig. 2&3).

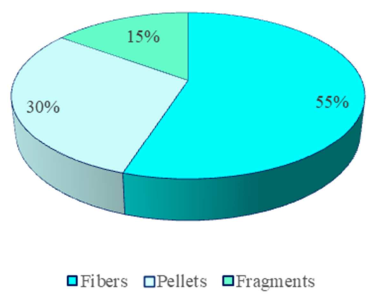

Fig. 2. Quantity of microplastics obtained in the Chinnamuttom water samples

Kooi *et al.* (2016) discovered that fibers are more prone to vertical redistribution in the upper ocean owing to their reduced rise velocity relative to similarly sized fragments. The diminutive dimensions and flexibility of fibers make them a particularly hazardous aliment for aquatic organisms. Numerous sources, including unregulated effluent entering coastal water, laundry-introduced textile and garment fragments, and fishing, can contribute to the presence of fiber (Hamed *et al.*, 2023).

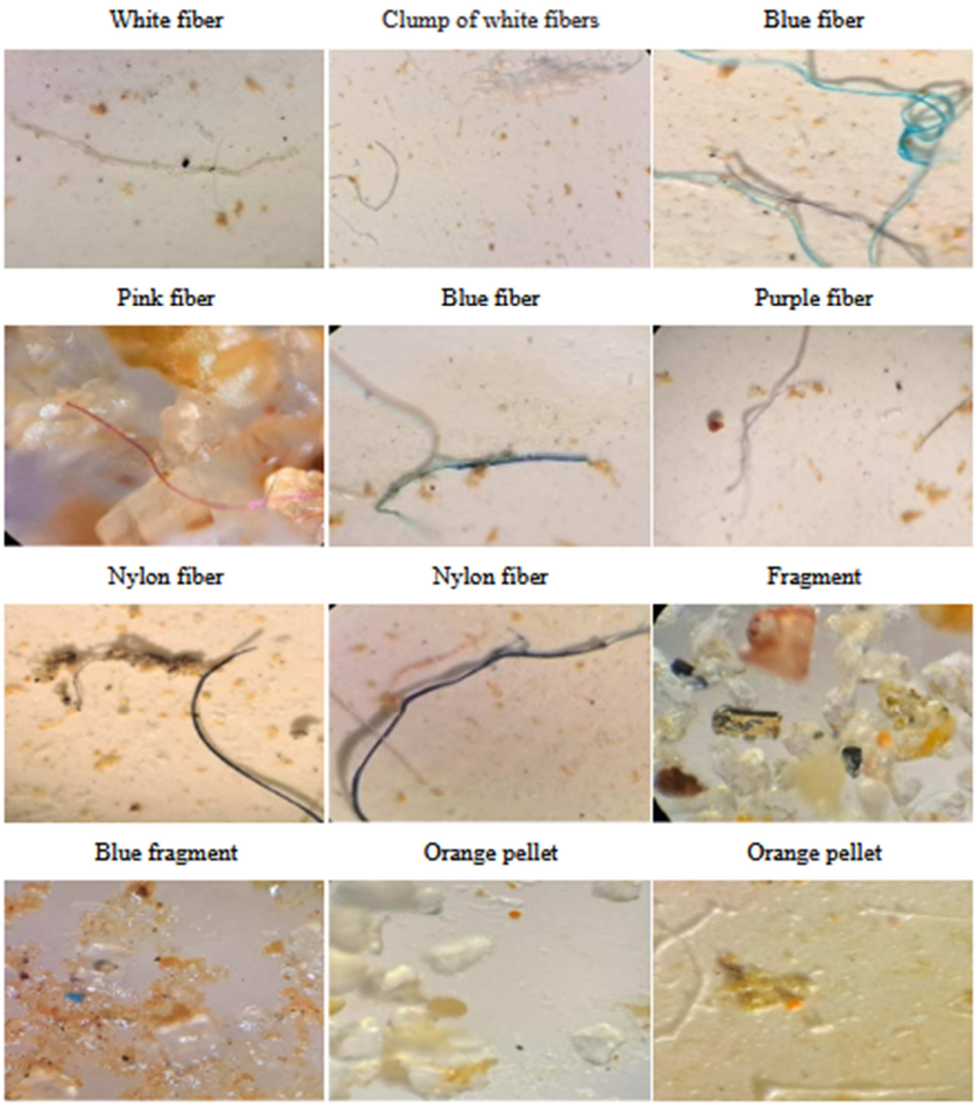

Fig. 3. Different types of microplastics observed in the Chinnamuttom water samples

The presence of fragments and particles in the water samples may be indicative of the degradation of macroplastics that have entered the water. The potential sources of microplastic in the coastal areas include the widespread use and inadequate waste management in the Chinnamuttom area, as well as the emergence of peri-urban communities upstream. Koongolla *et al.* (2018) detected microplastic in 70%

of the water samples from Southern Sri Lanka. Results showed that microplastic composition was significantly influenced by PE and PP, while fragment morphology was predominant. The study also reveals the presence of microplastic pollution in the water column in countries primarily driven by tourism.

A crucial element in the dietary exposure of microplastics to the resident species is the hue of the materials (Arias *et al.*, 2019). Water sample obtained from Chinnamuttom revealed the presence of microplastics in a range of colours, such as black, purple, white, blue, pink and orange.

The regular use of coloured plastic items could worsen the increase of plastic waste in saltwater, thus playing a substantial role in the widespread presence of these pervasive microplastics. The diverse range of MP colours indicates a possible similarity to the colours observed in natural marine foods. Novotna *et al.* (2019) demonstrate that animals consistently prefer to ingest microplastics that mimic the colour of their prey, underscoring the crucial influence of colour in the consumption of microplastics by marine species.

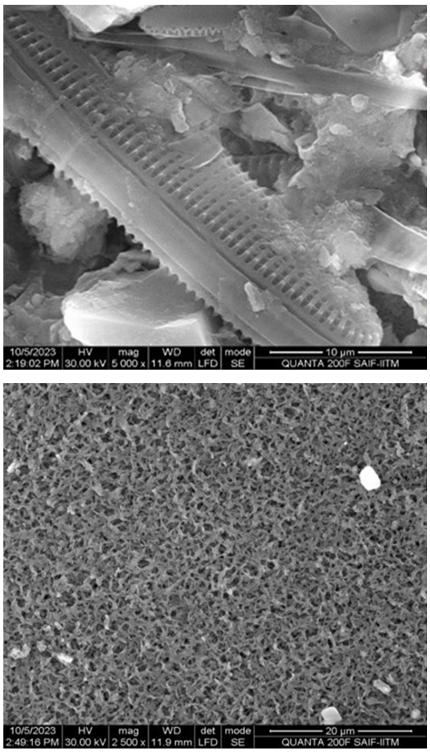

Fig. 4. Scanning microscopic images of microplastics

Scanning electron microscopic analysis

SEM analysis is an advanced technique that enables precise visualization of the size, morphology, and surface features of microplastics with high resolution. Scanning electron microscopy analysis of the microplastics revealed a diameter of 10-20 µm (Fig. 4). Similarly, the study carried out by Ding *et al.* (2019) in the Xisha Islands, South China Sea, reported the presence of microplastics ranging in size from 20 µm to 5 mm.

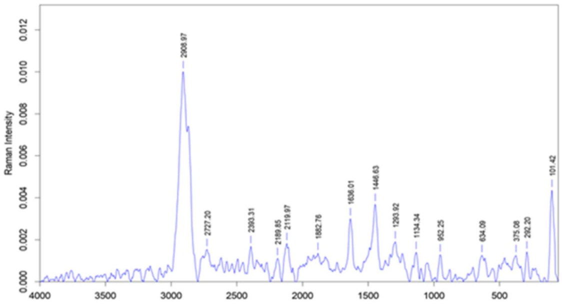

Fig. 5. Analysis of Raman shift and intensity spectrum

The size of microplastics significantly influences the absorption and spread of these persistent contaminants among diverse species at various trophic levels (Bobori *et al.*, 2022; Becucci *et al.*, 2022). The small size of the particles found in the Chinnamuttom samples suggests that they are likely secondary microplastics formed from the degradation of larger plastic items in the environment.

The present study obtained SEM images that display microplastics with rough, porous and evenly distributed surfaces with sharp edges. This could be attributed to the deterioration of plastics caused by environmental exposure along the banks, resulting in surface fragility and microcracking. This process produces microparticles that are carried into the water through wind or wave action (Andrady, 2011). Similarly, a study by Liu *et al.* (2019) examined the presence of microplastics in the sediments of Poyang Lake, China. The results showed that SEM images of the different microplastics showed different levels of surface roughness. This highlighted the complex surface topography features that are often described as rough, porous, cracked, or severely damaged.

FT-Raman spectroscopy analysis

FT-Raman spectroscopy is a valuable technique for identifying functional groups in microplastics by measuring the vibrational frequencies of molecular bonds (Araujo *et al.*, 2018). The examination of the Raman spectrum revealed the presence of several functional groups, such as C-H, Aldehyde, P-H (Aromatic), N–H, N–O, (C–N) aromatic amines, (C–C), and C–O. The polymers of microplastics, particularly polystyrene and nylon, exhibited these functional groups, each identified by their unique vibrational peaks (Fig. 5).

Polystyrene

The spectrum displays pronounced high-frequency carbon-hydrogen (C-H) vibrations at 2908.97 cm^{-1}. Liu *et al.* (2020) observed that polystyrene particles exhibited distinctive high-frequency vibrations linked to the presence of hydrogen. The vibrations linked to carbon-carbon bonds at lower frequencies are approximately quantified at 900 cm^{-1}. The occurrence of C-H vibrations exceeds that of C-C vibrations, attributed to the lower mass of hydrogen in relation to carbon. The vibrational frequencies of two carbon atoms connected by double bonds (C=C) are observed around 1600 cm^{-1}, while two carbon atoms linked by a single bond (C-C) demonstrate vibrations at roughly 900 cm^{-1}.

Nylon

Nylon shows clear peaks at 3300 cm^{-1} and 1636.01 cm^{-1}, corresponding to N-H stretching and the presence of amide bonds (C-H and C=O). The observed characteristics align with the known composition of nylon, categorized as a polyamide polymer. The identification of polystyrene and nylon emphasizes the existence of both consumer and industrial sources, illustrating the widespread occurrence of synthetic polymers in marine environments.

The release of microplastics into the aquatic environment is attributed to the operation of watercraft and fishing vessels in the Chinnamuttom region. The degradation of plastic components found in the paints, coatings, and equipment utilized in these vessels over time result in a significant contribution to the microplastic pollution in the water. Fishing gear detritus is the main contributor to plastic pollution in fishing areas (Li, 2019). The effects of fishing and tourism pose numerous challenges for these regions. Thus, Chinnamuttom is presently encountering a considerable issue stemming from the serious risk that microplastic pollution presents to the marine ecosystem.

Conclusion

This study underscores the substantial prevalence of microplastics in the coastal waters of Chinnamuttom. The weight of the dried microplastic particles extracted from the water samples is approximately 70 mg per 5 liters. Microplastics existed in several forms, including fibers, pellets and fragments, and are found in colours such as white, blue, purple, orange and pink, with fibers constituting the largest proportion at 55%. SEM examination revealed particles of 20 µm, while Fourier-transform Raman spectroscopy detected particular polymers, such as polystyrene and nylon. The study revealed that fishing operations are the primary cause of this pollution, as the degradation of fishing gear, boat equipment and other plastic materials contributes microplastics to the marine ecosystem.

The Chinnamuttom Coast is celebrated for its breathtaking scenery and abundant marine life. Nonetheless, beneath its attractive exterior, microplastic pollution harbors a hidden threat. This investigation presents findings regarding the presence of microplastics in the marine waters adjacent to the Chinnamuttom coast. To address the issue of microplastic pollution, it is crucial to enhance public awareness. It is crucial to conduct additional studies on the occurrence and effects of microplastics in the waters of Chinnamuttom.

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