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Prevalence of Plastic Debris in Beach Sediments of Sutrapada, Saurashtra Coast of Gujarat, India

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***Abstract*:** This study evaluates plastic debris occurrence and physical characteristics from selected stations in beach sediments at Sutrapada, Saurashtra coast of Gujarat, India, from November 2020 to April 2021. Sutrapada Chowpatty (Station 1) and Sutrapada Bandar (Station 2) were selected for beach sediment sample collection. The abundance of macro-plastics, meso-plastics, and microplastics in stations 1 and 2 ranged between 2.9 to 8.5 and 3 to 10.1 items/m^2, 5.5 to 10.1 and 3.55 to 8.72 items/m^2, 4.33 to 20.33 and 6.83 to 16.33 items/100g, respectively. At Stations 1 & 2, the dominant macro-plastic shape, size and colour were fragment and fibre, >2.5 cm and 5 cm and white and blue, respectively. At Stations 1 and 2, the dominant meso-plastic shape, size and colour were fragment and thermocoel, 1 cm – 1.5 cm and 1.5 – 2 cm (both stations) and white and yellow, respectively. Stations 1 and 2, dominated by microplastic shapes, size and colour, were fibre, 1-2 mm & 2-4 mm and black for both stations, respectively. These results could be attributed to fishing, small-scale fisheries business, and tourism activities in a coastal town. The present study provides the origins of plastic waste in coastal areas, laying the groundwork for formulating sustainable, enduring plans and strategies to manage and control plastic pollution in the coastal environment.

***Keywords*:** Plastic pollution, Beach sediment, Microplastic, Physical characteristics, Sutrapada

Plastic is manufactured by synthetic or semi-synthetic organic polymer and is cost-effective, lightweight, robust, long-lasting, and corrosion-resistant (Thompson et al 2009). Ultimately, every plastic waste finds its way into marine environments as debris (Hopewell et al 2009). Plastic debris is classified according to size: macro-plastics, meso-plastics and microplastics (Cheshire et al 2009). Macro-plastics refer to plastic fragments larger than 2.5 cm, representing the most prominent and easily detectable type of debris along shorelines and readily removable. Meso-plastics consist of particles ranging from 5 mm to 2.5 cm. Unlike larger macro debris, meso-plastic particles are frequently buried and evade removal during cleanup efforts. Plastic particles smaller than 5 mm are called microplastic (Arthur et al 2009). Microplastics in the environment can be divided into two categories: primary microplastics and secondary microplastics. Primary microplastics may be deliberately manufactured to be that size (GESAMP 2019), whereas secondary microplastics are generated from weathering or breakdown of macro-plastic and meso-plastic items. Primary data and additional information regarding coastal litter in India can be accessed from the different regions across the country, such as the Nicobar Islands (Sen 2003), Gulf of Cambay (Reddy et al 2006), Karnataka coast (Sridhar et al 2009), Northern Gulf of Mannar (Ganesapandian et al 2011), Tamil Nadu (Kaladharan et al 2012), urban beaches in Mumbai (Jayasiri et al 2013), Mangalore coast (Sulochanan et al 2014), Kerala, Karnataka and Chennai coast (Kumar et al 2016) and Tamil Nadu (Sathish et al 2019). Plastic items are also found in the digestive systems of deceased fishes (James et al 2020), zooplankton (Collignon et al 2012), crustaceans (Daniel et al 2020), mussel (Karlsson 2017), bivalves (Li et al 2015), seabirds and marine mammals (Lusher 2015).

Sutrapada is a coastal town near Veraval on Gujarat's Saurashtra coast and has Gujarat Heavy Chemical Pvt. Ltd. (GHCL), a major chemical industry. The town also has a fishing harbor that supports local livelihoods. Sutrapada Chowpatty supports local tourism activities, especially during holidays. This led to the widespread use of plastics, including fishing nets, packaging, and fishing debris. Studies are needed to assess the occurrence and abundance of plastic debris in Sutrapada. This study aims to evaluate the occurrence of plastic debris, its distribution and the physical characteristics of the beach sediment samples along the Sutrapada coast.

MATERIAL AND METHODS

Study area: The two stations were selected for sampling, namely Sutrapada Chowpatty (Station 1) and Sutrapada Bandar (Station 2), situated at 20.838429° 70.477588° and 20.833949° 70.487397° located on the Saurashtra Coast of Gujarat, India. These stations exhibit a combination of rocky and sandy substrates and are characterized by a rich assortment of molluscan shells, seaweeds and coastal fish species. Sutrapada scenic chowpatty draws many visitors

daily and hosts religious fairs, especially on weekends, showing anthropogenic stresses and their impact on natural ecosystems.

Sampling procedures and collection: The study was conducted for six months, from November 2020 to April 2021. At each chosen location, sampling was carried out using a 1 m^2 quadrate at monthly intervals. The sampling was conducted along two-line transects, each spanning 100 m from the high tide line and fixed during the sampling period. Triplicate samples were collected from random areas along the shoreline within pre-decided line transects. Plastic debris was classified into three groups based on particle size given by Cheshire et al (2009): macro-plastics (> 2.5 cm), meso-plastics (between 5 mm-2.5 cm) and microplastics (< 5 mm), respectively. Due to their larger dimensions, macro- and meso-sized plastic fragments were manually gathered from the quadrats and filtered through a 5 mm sieve. The retained macro-plastic and meso-plastic debris samples were analyzed using the visual identification method (GESAMP 2019). To prevent contamination, all collected samples were promptly packed before transportation to the laboratory to quantify and analyses physical characteristics such as shape, type, size, and colour.

Sampling and extraction of microplastic: Within a quadrate, one kg surface sediment sample is collected at 2 cm depth and transferred to the laboratory for further processing. The method proposed by Qiu et al (2016) was used to extract microplastic from sediment samples. To identify the presence of microplastics in the sample, the filter paper underwent examination using a stereo-zoom microscope (40x) equipped with a digital camera. The identified microplastics were separated and photographed individually according to their shape, size and colour, and all relevant information was recorded and documented.

RESULTS AND DISCUSSION

Macro-plastics abundance: The abundance of macro-sized plastics in the beach sediment varied between 2.9 to 8.5 and 3.0 to 10.1 items/m^2 at station 1 and station 2, respectively. The average abundance of macro-plastics at station 1 and station 2 was 6.5 and 6.9 items/m^2 was attributed to fishing activities, small-scale fisheries business, and waste disposal proximity, indicating that both stations significantly contributed to land-based sources of pollution. Jeyasanta et al (2020) also observed that fishing and recreational activities majorly cause macro-plastic distribution.

Physical characteristics of macro-plastics: The shape of macro-plastics identified from beach sediments at Station 1 was dominated by fragment-shaped followed by fibre, filmed plastic, thermocol, pellet, plastic pouches, bottles, food wrappers and cutleries, which might be due to tourism activity, ocean currents and land-based sources (Table 1). Allsopp et al (2006) reported the plastic waste on the shoreline likely came from external sources and may have been carried by ocean gyres, winds, and sea currents. Station 2 was fibre-shaped macro-plastic dominant, followed by fragments, foamed plastic, and plastic pouches, which might be due to fishing-related activities and small-scale business proximity to coastal areas. Lee et al (2015) observed that fibre-shaped macro-plastics were dominant, comprising 54.7% of the plastic content across twelve South Korean beaches. Station 1 dominant sizes ranged between >2.5 cm and 5 cm, followed by 10-20 cm, >40 cm, 5-10 cm, and 20-40 cm. Furthermore, Station 2's dominant sizes ranged between >2.5 cm and 5 cm, followed by 20-40 cm, 10-20 cm, 5-10 cm, and >40 cm, respectively. The most common sizes were due to the fragmentation of large plastic fragments into small macro-sized plastics.

In station 1, white-coloured particles were dominant, followed by transparent, red, green, blue, brown, yellow, black, and grey. In station 2, blue-coloured particles were dominant, followed by white, transparent, yellow, brown, and black. The variety of colours could be attributed to the diverse origins of the plastic, stemming from different sources. The smaller and multiple colours macro-plastic particles might appeal to marine organisms as feed, potentially elevating their chances of being ingested (Behera et al 2021). Blaskovic et al (2017) observed transparent and white colours were the dominant plastic litter reported in sediments from the Croatian marine protected at Telascica Bay.

Meso-plastics abundance: Meso-sized plastic items were found in samples collected from beach sediment stations at Sutrapada. The abundance of meso-sized plastics varied between 5.5 to 10.1 items/m^2 and 3.5 to 8.7 items/m^2 at stations 1 and 2, respectively. The average abundance of meso-plastics was 7.1 and 6.1 items/m^2 at stations 1 and 2, respectively. Jeyasanta et al (2020) reported an abundance of 9.3 items/m^2 of meso-plastics from the beaches of the Tuticorin, Southeast coast of India.

Physical characteristics of meso-plastics: Fragment-shaped meso-plastics were dominantly identified at station 1, followed by fibre, thermocoel and plastic pouch. At station 2, thermocoel was the dominantly identified meso-plastic, followed by plastic pouch, fragments and fibre, which might be the due breakdown of larger plastic through mechanical forces, photolysis, thermo-oxidation, thermo-degradation and possibly via biodegradation processes (Zhao et al 2015). Disposal waste and damaged fishing nets are also believed to be important sources of meso-plastic fibres (Browne et al 2011). Meso-plastic sizes ranging from 5 mm to 2.5 cm were

reported from sediment at station 1 with dominant sizes ranging between 1 - 1.5 cm, followed by 1.5 cm - 2.0 cm, >5 mm - 1.0 cm and 2 cm - 2.5 cm. At station 2, dominant sizes were reported to range between 1.5 cm - 2 cm, followed by 1 cm - 1.5 cm, >5 mm - 1 cm, and 2 cm - 2.5 cm. The total of eight colours comprised of white, yellow, red, green, transparent, black, blue, and brown were reported from both stations. At station 1, white-coloured particles were dominant, while at station 2, yellow-coloured particles were dominant. Jeyasanta et al (2020) reported similar coloured meso-plastics from Tuticorin beaches on the southeast coast of India. Blettler et al (2017) described varied colours as being reported due to the origin of plastics from different sources and the intensive weathering process of macro-plastics.

Microplastics Abundance and Physical Properties

Microplastics abundance: The abundance of microplastics in the beach sediment varied between 4.3 to 20.3 items/100 g and 6.8 to 16.3 items/100 g at stations 1 and 2, respectively. The average abundance of microplastics was 10.5 and 10.5 items/100 g, possibly sourced due to fishing activity generated waste, dense fisher population, and regular influx of beach visitors. Fishing is a primary contributor of microplastics to beaches, given that they serve as primary fishing hubs for nearby fishing villages (Dowarah and Devipriya 2019). Dekiff et al (2014) reported that the presence of microplastics in beach sediment is attributed to anthropogenic activities.

Physical characteristics of microplastics Fibre-shaped microplastics were dominated in station 1 and station 2, respectively. At station 1, other shapes were fragments, films, foam, and pellets. In contrast, at station 2, fragments, films, foam, and pellets were reported, possibly due to the segregation and repair of fishing nets and small-scale fisheries business proximity to the beach. Fibre and fragment-shaped microplastic emerged from fisheries activities and small-scale businesses (Lusher et al. 2017 and Sathish et al. 2019). The sizes of microplastics reported from beach sediment ranged between <0.5 mm to 5 mm. The major size range at station 1 was 1 mm - 2 mm while station 2 was 2 mm - 4 mm. Other size compositions at station 1 were 2 mm - 4 mm, 0.5 mm - 1 mm, >0.5 mm, 4 mm - 5 mm, while at station 2, was 1 mm - 2 mm, 0.5 mm - 1 mm, 4 mm - 5 mm and >0.5 mm, respectively. Young and Elliot (2016) reported that most particle sizes ranged from 2-4 mm at Kamilo Beach and Kahuku Beach in Hawaii during the entire study period.

In total, seven different coloured microplastics were

Table 1. Composition of physical characteristics of macro-plastic from beach sediment

Shape composition (%)			Colour composition (%)			Size composition (%)		
Shape	Station 1	Station 2	Colour	Station 1	Station 2	Size(cm)	Station 1	Station 2
Fibre	18	43.2	White	40.3	20.1	> 2.5-5	38.5	39.1
Fragments	48.5	22.2	Transparent	16.0	15.5	5-10	12.1	8.0
Film	9.0	18.5	Red	11.5	0.0	10-20	25.0	19.0
Thermocoel	7.0	0.0	Green	10.6	0.0	20-40	4.2	32.3
Pellet	6.0	0.0	Blue	9.2	40.0	> 40	20.1	1.5
Plastic pouch	4.5	16.5	Brown	5.2	7.8			
Bottles	3.0	0.0	Yellow	3.50	10.8			
Food wrappers	2.5	0.0	Black	1.82	6.0			
Cutleries	1.3	0.0	Grey	1.7	0.0			

Table 2. Composition of physical characteristics of meso-plastic from beach sediment

Shape composition (%)			Colour composition (%)			Size composition (%)		
Shape	Station 1	Station 2	Colour	Station 1	Station 2	Size(cm)	Station 1	Station 2
Fibre	22.1	10.5	White	29.7	23.5	0.5-1.0	21.5	19.8
Fragments	30.5	11.0	Transparent	8.4	9.5	1.0-1.5	34.5	30.0
Thermocoel	21.5	43.2	Red	18.8	17.7	1.5-2.0	28.9	33.4
Plastic pouch	16.7	25.6	Green	11.9	11.9	2.0-2.5	15.1	16.6
Bottles cap	2.0	3.0	Blue	3.3	4.9			
Straw	0.5	2.0	Yellow	20.8	25.5			
Irregular item	6.4	4.5	Black	6.9	6.7			

Table 3. Composition of physical characteristics of micro-plastic from beach sediment at station 1 & 2

Shape composition (%)			Size composition (%)			Colour composition (%)		
Shape	Station 1	Station 2	Colour	Station 1	Station 2	Size(cm)	Station 1	Station 2
Fibre	59.3	51.0	>0.5	13.4	9.0	White	23.1	18.5
Fragments	14.2	24.3	0.5-1.0	22.7	18.3	Transparent	10.3	14.3
Film	12.0	10.7	1.0-2.0	31.3	27.3	Red	14.4	12.5
Foam	10.2	8.2	2.0-4.0	24.1	32.0	Green	6.8	12.5
Pellet	4.0	5.5	4.0-5.0	8.9	13.2	Blue	11.4	16.0
						Yellow	3.7	2.2
						Black	30.0	23.9

recorded from beach sediments. The black-coloured microplastics dominated at station 1 and station 2, respectively. At station 1, other colour compositions are white, red, transparent, blue, green, and yellow. In station 2, other colour compositions are white, blue, transparent, red, green, and yellow. The colour variation among microplastic particles may be due to their origin from different sources. Furthermore, the small size and multicolour of the microplastic particles may favour their intake by marine organisms (Sathish et al 2019), eventually leading to accumulation and transfer to higher tropic levels. Retama et al (2016) suggested that coloured microplastics attract predatory fishes since they resemble their prey and pose severe threats to marine ecosystems.

CONCLUSION

The plastic debris contamination of the beach sediment of Sutrapada town could be attributed to fishing activities, small-scale fisheries business, and anthropogenic activities. Further, ocean currents are responsible for plastic debris' widespread contamination through transportation across large distances. Meanwhile, continuous monitoring of plastic debris sources and contamination along the beaches is much needed, and awareness among the locals is required through regular beach cleaning activities. These studies highlight the significant risks posed by introducing plastic debris into aquatic environments, the need for public awareness, and the importance of its impact on marine ecosystems and human health.

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