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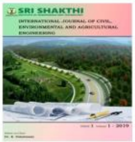

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Quantification and characterisation of microplastic pollution and its ecological risk in the coastline of Tuticorin, India

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Abstract: Microplastics (MPs) are present practically everywhere in the coastal ecosystems, including the sediment of beaches and wetlands as well as the columns of surface and subsurface waters. Marine MPs are most frequently found in the near shore zones. Due to their potential negative impact on ecosystem functions, MPs have become a significant environmental problem worldwide. Contamination by microplastics has been well-documented around the world and it has drawn the attention of the scientific community, governmental and international organisations and the general public. In the present study, involving the isolation, assessment and characterisation of MP debris collected from six coastlines with recreation and fishing activities in Tuticorin district, the most common MP polymers identified are polypropylene, polyethylene, polyamide and polystyrene. The maximum number of MPs are found in the sediment samples of Tiruchendur (with an average of 8.33 5.3), and the least number of MPs are observed in the water samples of Aalanthalai (2 1.0). To assess the quality of water and sediment, we calculated the polymer hazard index (PHI), pollutant load index (PLI) and potential ecological risk index (PERI). Because of the presence of high-hazard polymers like polyamide (PA) and polystyrene (PS), the study areas have high PHI values (>1000). According to PLI values, water and sediment samples from Tiruchendur and Manapad are highly contaminated with MPs (PLI: 6.98 to 13.85), whereas samples from Aalanthalai, Kayalpattinam and Roche Park are less contaminated (PLI: 1.87 to 3.43). The PERI values of sediment samples from Tiruchendur show the highest ecological risk (PERI: 416.783). On the basis of anthropogenic activities, centres with recreational activities have substantially greater MP concentrations than the fishing locations, and the sediment samples are considerably more polluted with MPs than the water samples taken from the same locations, according to PLI values.

Keywords: Microplastics, Sediments, Water, Polymer hazard index, Polymer load index, Potential ecological risk index, Coastlines of Tuticorin

Introduction

The contemporary world cannot function without plastic. Since 1970sthe manufacture of plastic has grown quickly to meet the enormous demand for it throughout the world. In 2019, 368 million tonnes of plastics were produced globally [1]. Due to the improper handling of plastic waste, the widespread use of plastic has, unfortunately, also led to significant volumes of plastic leaking into the environment. Due to its role as the primary source of microplastics in water bodies, plastic trash is now thought to pose direct and indirect risks to human health and environment [2]. MPs can be produced in the environment by the gradual disintegration of larger plastic pieces through UV-induced, mechanical, and biological degradation processes [3-6]. The majority of MPs in the marine environment is believed to have been brought directly from different land sources including industries and consumer items because the breakdown processes are relatively sluggish in most environmental settings [6, 7].

In recent years, microplastics in the oceans have emerged as a new environmental problem. Microplastics are plastic flecks that range in size from 0.001 to 5 millimetres [8]. According to their mode of origin, they can be further separated into primary and secondary microplastics [8]. Primary microplastics are created as tiny particles, such as those used in drug delivery media and the microbeads used in toothpaste and cosmetics, whilst secondary microplastics are formedas a result of the gradual degrading of larger plastic pieces due to UV radiation, temperature changes, biological deterioration, and physical damage [[9, 10]. Physical abrasions with sediments and the hydrolytic action of saltwater accelerate the degradation process [11].

Microplastics are widely dispersed in the seas and have been shown to accumulate in the marine as well as the freshwater ecosystems worldwide, as demonstrated by a number of studies conducted over the past ten years [12]. In the ocean, microplastics can passively migrate across great distances [13]. Many authors consider the terms "microplastics" and "microlitter" to have distinct meanings. distinguish between microlitter and mesolitter, defining the former as the scarcely perceptible particles that pass through a 500 µm filter but trapped by a 67 µm sieve (0.06-0.5 mm in diameter) [14]. Seawater frequently contains plastic particles with sizes ranging from a few µm to 500 µm (5 mm) [15, 16]. Microplastics, in contrast to bigger fragments, are not clearly visible to the naked eye; even resin-pellets (mesoplastics) combined with sand are difficult to distinguish. Naturally, net sampling does not capture the smaller microplastics, and there is currently no approved standard approach available for counting them in sand or water [17].

The widespread use of plastics in manufacturing and consumer goods and the consequents improper treatment of plastic trash are the main causes of MP pollution. Depending on the most detailed calculations, there may be between 5 and 51 X 10^12 (5- 51 trillion) particles in the marine environment [18]. MPs are mostly stored in the marine ecosystem, with small exports to the terrestrial environment occurring in the form of buried beach debris, sediment extraction, and the capture of marine organisms for human consumption. In benthic habitats, thick and biofouled MPs may settle. Due to the difficulty in accessing deepwater sediments, which calls for highly specialised equipment and prolonged boat time, there are not many samples currently available. MPs have been discovered using deep sea cores in the Mediterranean at depths up to 3,500 m [19].

The objective of the current study is to define and quantify the microplastic contamination and to assess the ecological risk along the beaches of Tuticorin district of Tamil Nadu. Given the range of nearby coastal settings, the chosen places make a great research area to look into microplastic contamination in the district.

Materials and Methods

Using a methodology identical to that used by Ross, water and sediment samples were collected in 2022 from six coastal locations in the Tuticorin district (Figureure. 1).

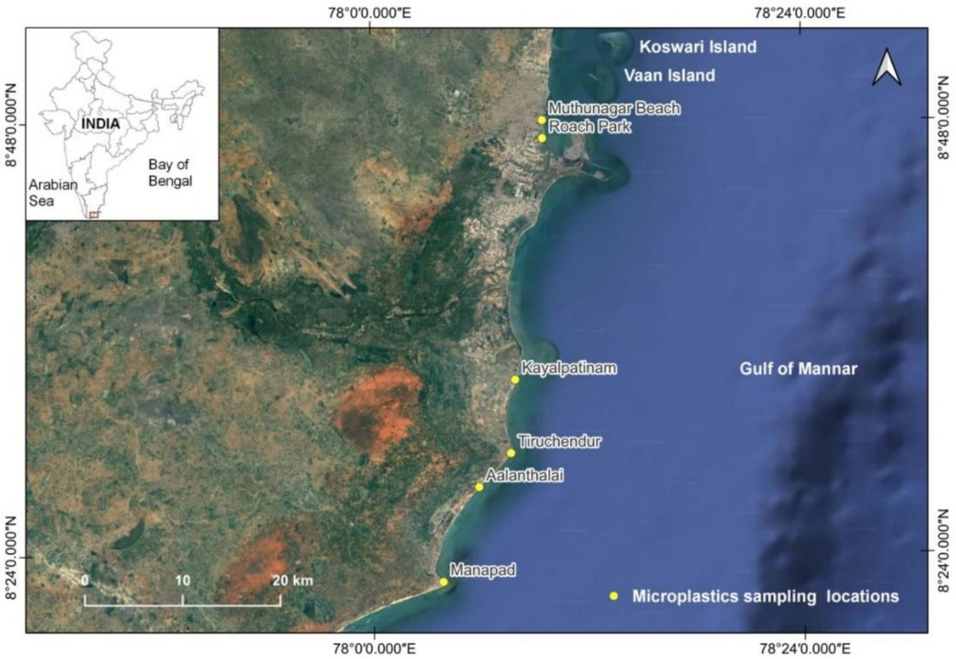

Figure 1. locations of samples collected from the coastlines of Tuticorin, India

The six chosen sites are described below. Site 1 Kayalpattinam:two distributaries of the perennial river Thamirabarani, traversing the taluks of Srivaikundam and Thiruchendur and reaching the sea at the estuaries of Kayalpattinam and Punnakayal, meet at Kayalpattinam (8.5612º N and 78.1331ºE), which is located at approximately 23 km south of Tuticorin. Huge quantities of domestic and industrial wastes are brought by the river. A key element influencing the mixing of sewage in the coastal waterways is river runoff. Site2 Tiruchendur is located at 36 kilometres south of Tuticorin (8.4933ºN and 78.1282º E). Millions of pilgrims from all over India visit the highly well-known seaside temple in this town [20]. Site 3Aalanthalai (8.4621ºN and 78.0984ºE) is a centre of heavy fishing and has a renowned church close to the shore. Site4 Manapad, situated halfway between Tuticorin and Kanyakumari (8.3747ºN and 78.0645º E), has a well-known church on the coast. The greatest natural surfing spots in India are located at Manapad. Fishing is primarily done in the beaches. Site 5 Muthunagar Beach (8.8086ºN and 78.1629ºE) is a popular recreation area in Tuticorin city. Site 6Roche Park (8.7841ºN and 78.1593ºE) is a famous recreation destination, where fishing is also a major activity of the nearby fishing village.

The intertidal area of the sea, which has the largest concentration of debris from recent storms, was chosen for the collection of both types of samples. Sampling was done in three replicates. The top2 cm of silt in this zone was collected into glass jars and put in a 0.25 m quadrat in the centre of the area. Large plastic debris was taken by hand picking.

Microplastic analysis in water samples

Following the methods, we extracted MPs from water samples. To 1 L of water sample 30 mL of hydrogen peroxide solution (30%, v/v) was added, and the preparation was allowed to remain for72 hours at room temperature. Cellulose nitrate filter sheets (0.8 m) were used to isolate MPs. The filter sheets were then left to air-dry in separate Petri dishes at room temperature, and then examined optically under a stereotype microscope (Nikon, Tokyo, Japan) at a 40X magnification and photographs of probable MPs were taken.

Microplastic analysis in sediment samples

Using a stainless-steel spoon, the top 3 cm of silt in each micro quadrat (0.0625 m^2) was removed and taken to the lab. Each sample had around 1 kilogram of dry sediment. Calculations were made to determine the number of microplastic objects per square metre. In the lab 200 g of each sediment sample was treated with 30 ml of 10% hydrogen peroxide in order to get rid of any organic compounds that were naturally present. A 72-hour period of room temperature digestion was permitted. The supersaturated sodium chloride solution, which was supplied at a ratio of three times the volume of the sample to make the microplastics float, had a density of 1.6 gm/l at 3.3 M, and was used to separate the microplastic particles using density separation. To ensure that all plastic fragments were eliminated from the sediment sample, NaCl-extraction was carried out two to three times. The samples were left at room temperature for 24 hours before the top portions of the solutions were filtered using 0.8 m cellulose nitrate filter papers. The filter papers were dried at room temperature in individual Petri dishes with lids. A dissecting microscope with a 40x magnification was used to examine and take photographs (Motic digital microscope). Doubtful plastic particles were subjected to a hot needle test [21]. Subsequently, following, the size, shape and colour of the microplastic particles on the filters were described [22]. The size of the particles was determined by analysing the microplastic pictures using the Digimizer programme, version 4.1.1.0.The MPs were put in five size classesnamely0.05 mm, 0.25 mm, 0.75 mm, 1 mm, and 5 mm. Based on their distinct shape, MPs were categorised as fibres, films, foams, and fragments. Taking into consideration the predominant surface colour, the MP colours were noted. The filters reflecting the various sample types and sampling locations were used to randomly pick the suspected microplastic particles for FTIR-ATR analysis (Thermo Nicolet model iS5).

Risk assessment of Microplastics

Polymer hazard index (PHI)

To assess the ecological impact of various MP polymer types, chemical toxicity is taken into account [23]. In the present study, the concentration and chemical make-up of MPs were both taken into account when assessing the possible dangers, they pose in surface sediments [24]. Polymer hazard index of MPs was calculated using the following formula:

$$\text{PHI} = \Sigma P_n \times S_n$$

Where "S_n" is the hazard scores of polymer types of MPs determined following [23] [22]."P_n" is the percentage of certain polymer types recorded at each sampling site, and "PHI" is the estimated polymer hazard index

Pollution load index (PLI)

An integrated pollution load index (PLI) was established based on [25] to evaluate the level of MP pollution in surface sediments of India's estuarine, coastal, and marine environments. PLI is correlated with MP concentration factors (CF_i) at each site as shown below:

$$CF_i = \frac{C_i}{C_{oi}}$$

$$\text{PLI} = \sqrt{CF_i}$$

The MP's CF_i is the product of the background MP concentration (C_i) and the MP concentration at each site (C_i) (C_{oi}). The background value was determined to be the MP concentration with the lowest value found in the sediment sample.

Potential ecological risk index (PERI)

Potential ecological risk index (PERI) is also used to assess the degree of contamination of MPs in the sediments [26]. The equations used to calculate the PERI are as follows:

$$C_f^i = \frac{C_i}{C_n^i}$$

$$T_r^i = \sum_{n=1}^{n} \frac{P_n}{C^i} \times S_n$$

$$E_r^i = T_r^i \times C_f^i$$

where, C_i and Cn^i are the concentration of pollutant 'i' (i.e., microplastic) and unpolluted samples, respectively. The toxicity coefficient (Tr^i) represents toxicity level and biological sensitivity. The toxicity coefficient is the sum of the percentage of certain polymers in the total sample (P_n/C^i) multiplied by the hazard score of plastic polymers (S_n).

Table 1. The hazard level criteria for MP pollution

Phi	Hazard Category	Pli	Hc	Peri	Risk Catagory
0 -1	I	< 10	I	<150	Minor
1 -10	II	-	-	150- 300	Medium
10 – 100	III	10-20	II	300- 600	High
100 – 1000	IV	20-30	III	600-1200	Danger
>1000	V	> 30	IV	>1200	Extreme Danger

Results and Discussion

Microplastic abundance in Water and sediment samples

The distribution and concentration of MPs in the water and sediment samples collected from the coastal locations in the present study are presented as mean ± (SD). Tiruchendur has the greatest concentration of MPs in water samples (15.7±1.53) (Figure1), whereas samples from Aalanthalai show the lowest concentration (4.7±1.15). The overall average of MPs found in the water samples taken from Kayalpattinam is 6.5±4.73, followed by 9±4.6 of Manapad, 14.3±2.1 of Roche Park, and 16±9.7 of Muthunagar Beach.

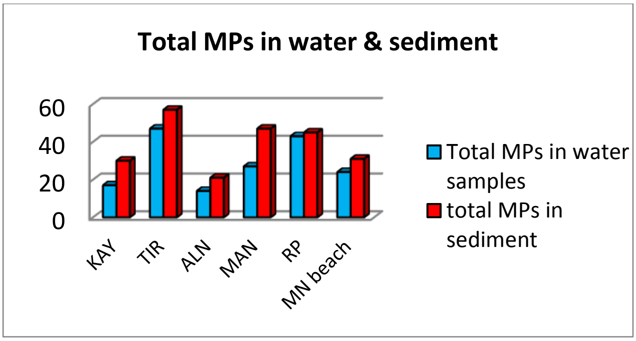

Figure 2. Percentage of microplastics in water & sediment

In sediments, Tiruchendur and Manapad show the most MPs with an average of 19±6 and 15.7±6.8 respectively. Aalanthalai has the lowest mean at 7±2.65. The mean count of MPs in the sediment samples is 10±2 in Kayalpattinam,15±4.6 in Muthunagar Beach and 10.3±6.5 in Roche Park.

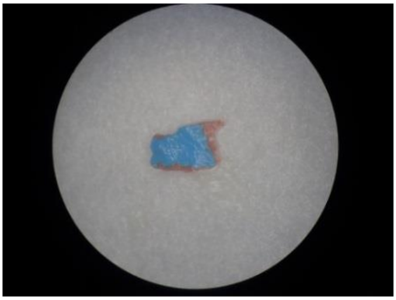

Figure 3. Fragment type of MP

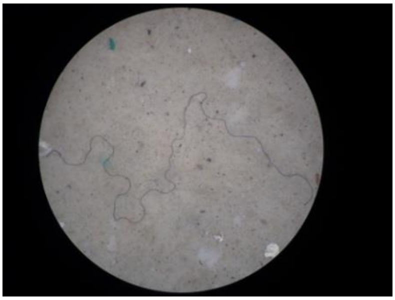

Figure 4. Fibre type of MP

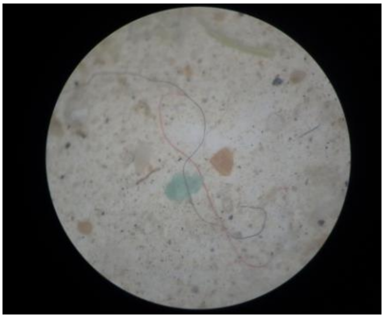

Figure 5. Foam type of MP

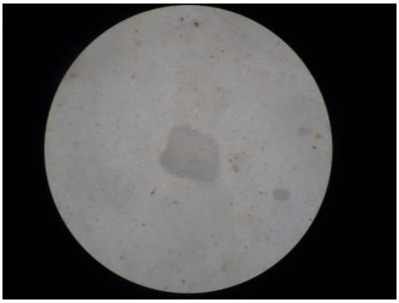

Figure 6. Film type of MP

Morphological analysis

Comparatively, the sediment samples have greater occurrence of microplastics. In water samples, fragment(45.5%) (Figure-3 &7) is the most commonly observed MP, followed by fibre (39.2%) (Figure 4), foam(3.7%) (Figure 5) and film (3.2%) (Figure 6).The presence of many synthetic fibres in the coastal environment puts the marine fauna to danger since the organisms might ingest the particles accidently or purposefully [17]. According to plastic filaments are present in 100% of the gular pouch samples, but fragments only present in 33% to 55% of the total gular pouches [27]. The size distributions of MPs in water samples are (Figure-8) >0.5mm (7.1%), 1- 2mm (23.1%), 2-3mm(29.8%), 3-4mm(13.0%) and 4-5mm(7.2%); and the colour distributions are green(19.7%)(Figure9), blue(17.7%), red(29.8%),black(21.2%)and transparent(11.6%). Lower trophic animals, in particular, may be at risk more from little synthetic fibres than from big ones since they take in any suitable-sized particles without discrimination. In the meantime, higher trophic level animals may consume microplastics by mistaking them for their prey [28, 29].

The FTIR study (Figure-10) shows polyethylene (PE) (Figure 15) to be the most prevalent polymer with a presence of 39.64%, followed by polypropylene (PP)with 37.84%, polyamide (PA) (Figure- 17) with 18.91%, while polyvinyl fluoride (PVF)has the least presence with 3.61%. In sediment samples (Figure- 11), fragment (55.77%) is the predominant MP type observed and the least type is film (1.89%). Most of the microplastics observed fall under the size (Figure -12) class of 1-2mm (24.68%), and the class >0.5mm has the least presence (9.85%).

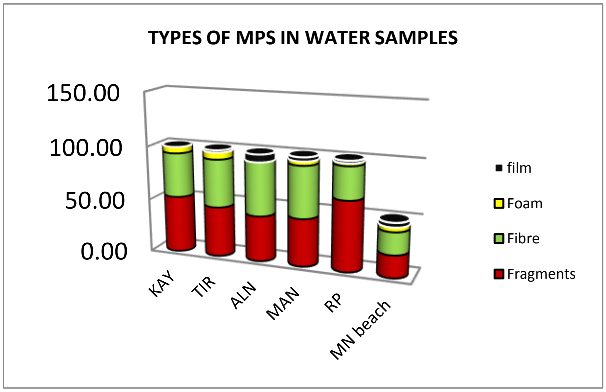

Figure 7. Types of MPs in water

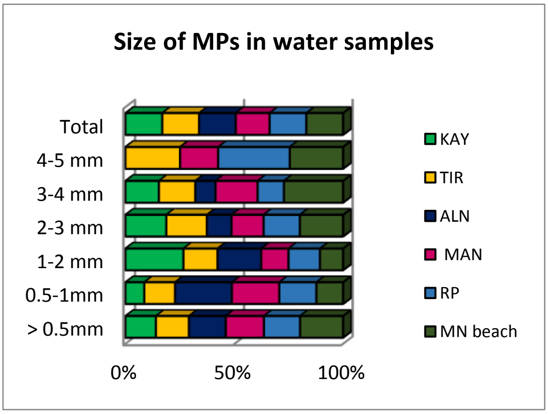

Figure 8. Size of MPs in water

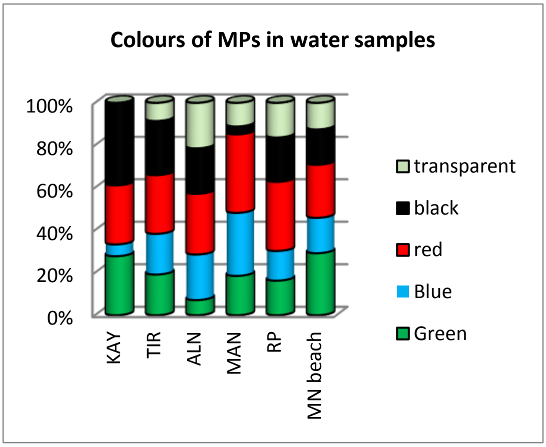

Figure 9. Colour of MPs in water

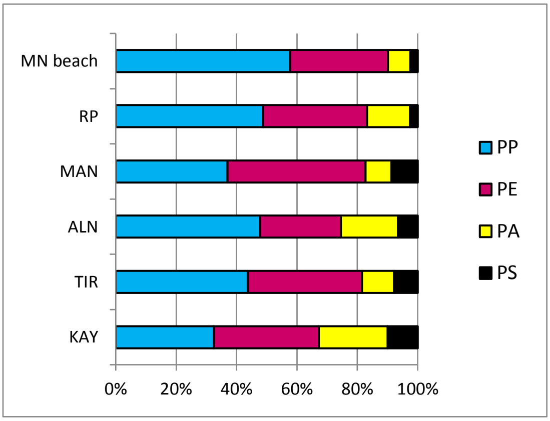

Figure 10- Polymers of MPs in water

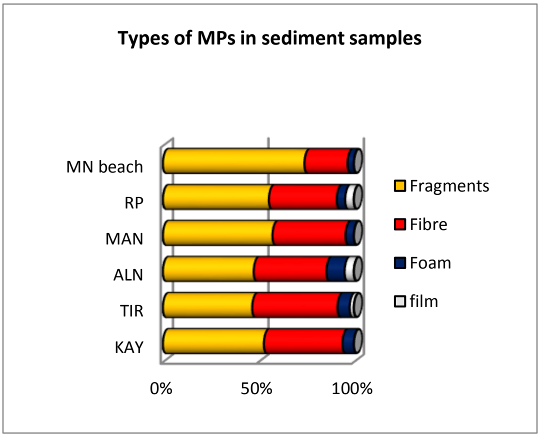

Figure 11. Types of MPs in sediment

The identified MP colours (Figure-13) are green (24.59%), blue (22.36), red(21.57), black(14.94%)and transparent (16.54%).The FTIR analysis (Figure-14) indicates polypropylene to be the most prevalent polymer (46.4%), followed by polyethylene(30.64%)(Figure-16), polyamide(15.85%) and polystyrene(7.11%) (Figure 18). The recreational sector is perhaps the main cause of the PE predominance in Tiruchendur. Greater usage of PE results in increased pollution, which has an impact on practically every type of habitat, including the terrestrial and marine biomes [30]. Aalanthalai has the lowest MP concentrations, which can be related to the area's lower level of urbanisation than the other sample sites.

According maritime zones tend to have higher concentrations of PE, PP, PS, PES and NY than riverine regions. The prevalence and variety of MP polymer types occurring along the Indian coast show a close connection with inland sources like urbanisation and industrialisation as well as sea-based sources like fishing and shipping.

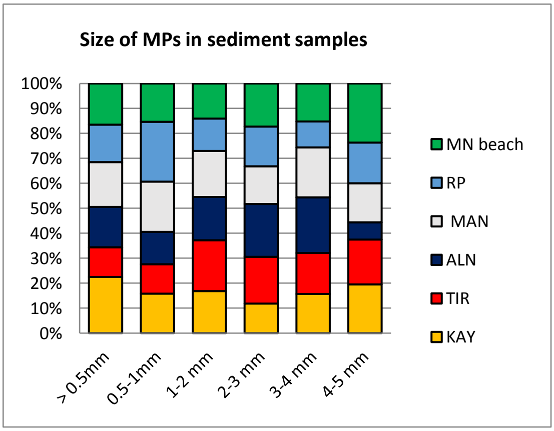

Figure 12. Size of MPs in sediment

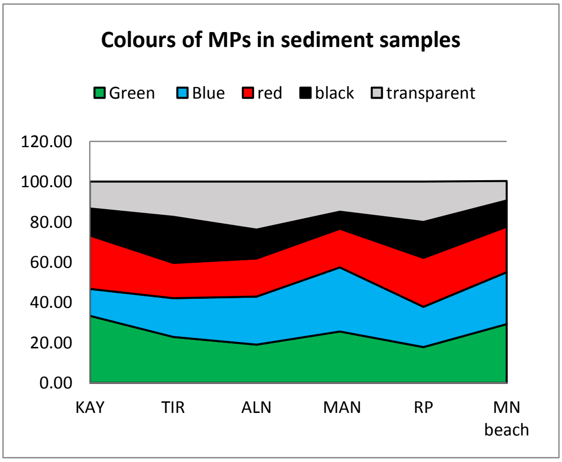

Figure 13. Colours of MPs in sediment

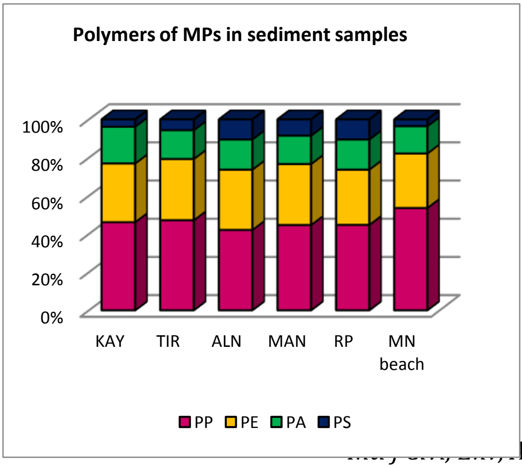

Figure 14. Polymers of MPs in sediment

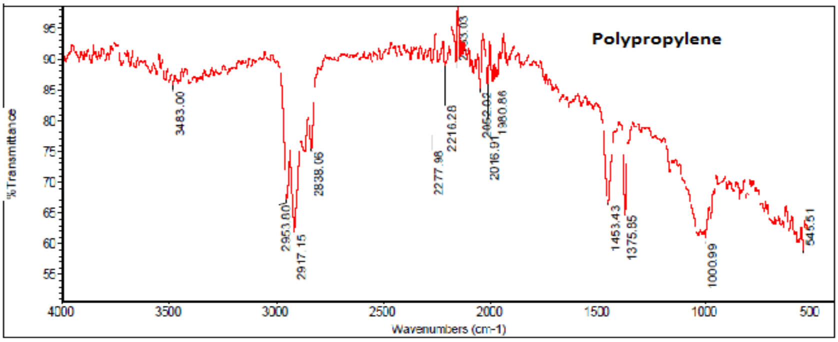

Figure 15. FTIR analysis polypropylene

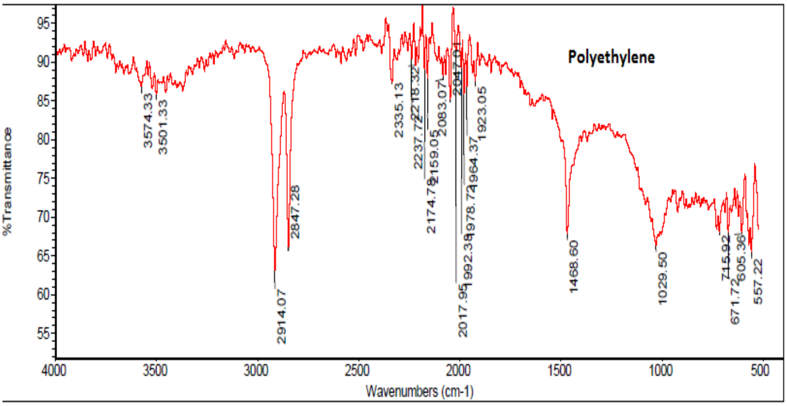

Figure16. FTIR analysis polyethylene

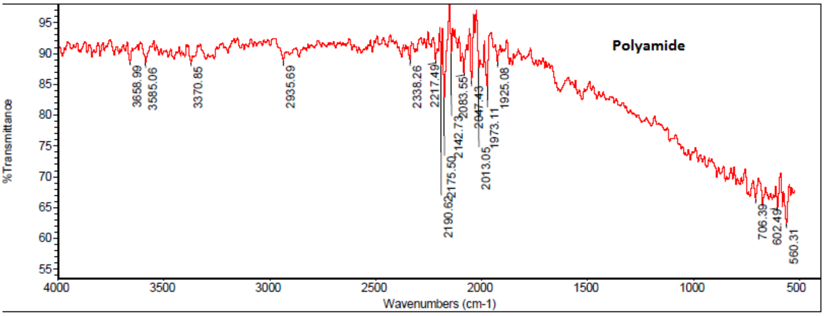

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Figure 17. FTIR analysis polyamide

A report that 80 percent of marine plastic waste is from land-based sources. The results of this study reveal that plastic pollution, particularly from recreational activities, is pervasive in the water and beach sediments of the sites examined.

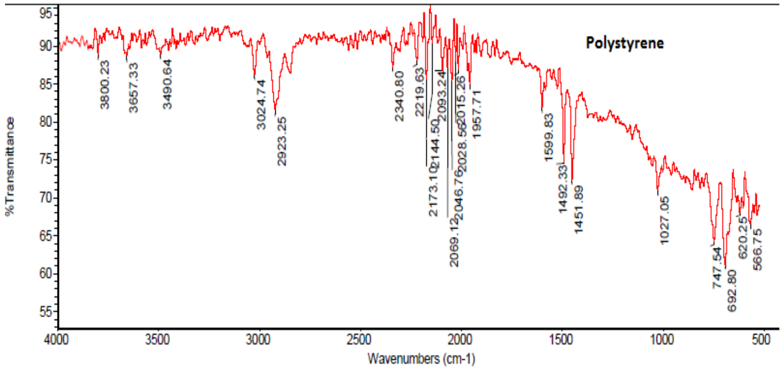

Figure 18. FTIR analysis polystyrene

Risk assessment of MPs in water and sediment samples

MPs have been found in a variety of animal taxa throughout the world, including zooplankton, bivalves, crustaceans, corals, fish, and seabirds. Because of this, top marine predators and humans may receive via food higher amounts of microplastics, which are active components of trophic interactions [31, 38]. According to several studies, microplastics affect organisms by causing physical harm and inflammation as well as by blocking the digestive tract, altering feeding and reproductive activities, lowering the progeny survival rate, and being generally toxic to cells [4,8,39,40]. MPs on the beach and sea surface undergo degradation by the action of the sun's energy and light and release dangerous chemicals. Over 50% of plastics include harmful chemical constituents, according to a hazard-ranking model based on the Globally Harmonized System of categorization and labelling of chemicals [23]. Using PHI, PLI, and PERI metrics, the ecological risk of MPs in terrestrial and marine sediments is evaluated. The total risk of MP pollution in India is classified as Hazard category IV to V based on PHI values (Table-1). The PHI values of MPs in the recreational areas are higher than those of the fishing sites. For example, the recreational sites like Muthunagar Beach, Manapad and Tiruchendur have higher PHI values (>1000) due to the presence of MPs with high-hazard score polymers such as PA and PS, whereas the fishing sites such as Aalanthalai and Roche Park have comparatively lower PHI values (< 1000). Any initiative seeking to reduce the hazard of microplastic pollution must take into account the chemical property of MPs.

The level of MP contamination is assessed using PLI [41]. In the present work the MP pollution load at each site was determined using PLI. In both water and sediment samples, the PLI values of Kayalpattinam, Aalanthalai, Roche Park are less than 10, which indicates the 'Hazard level I'. Tiruchendur (13.47), Manapad (11.09) and Muthunagar Beach (12.84) have

PLI values more than 10, indicating the 'Hazard level II'. According to PLI values, water and sediments from the fishing sites are less contaminated with MPs, while the water and sediments from the recreational sites are moderately contaminated. As PLI is determined using the ratio between the abundance of measured MPs and the background value, it appears that the chemical makeup of MPs has little impact on PLI. Regional human activities, including the pace of industrialization, population density, economic development, and sea-based activities, have an impact on the abundance of MPs in the maritime environment [41, 42]. The PLI depends on MP abundance, and so the pollution load increases when MP abundance increases. As PLI is calculated using the observed MP abundance in comparison to the baseline value, the variety of MP chemical composition appears to have a minor impact on PLI. The PLIs in the current research are significantly lower than those in previous studies [29], which may be because MPs with high dangers were not included in this analysis. Similar to this, a prior study found that the absence of MPs with high hazard scores caused a low PLI value of MPs pollution in the sediments of the mangrove environment [43].

The potential ecological risk index (PERI) values of Kayalpattinam, Tiruchendur and Manapad sediments show high ecological risk (PERI: 300-500). PERI is calculated based on the hazard score and prevalence of MP polymers. Due to the high abundance of PA and PS the sediments of Tiruchendur, Kayalpattinam and Manapad have the highest PERI. On the other hand, Muthunagar Beach, Roche Park, and Aalanthalai, where PA and PS are less abundant, have only slight (PERI150) to medium (150-300) ecological risk. Water from the same places also shows medium (PERI 100-250) ecological risk. The preliminary assessment of the ecological risk brought about by MP contamination in the water and sediments of fishing and recreational areas along the beaches of Tuticorin was done in this study by the combined use of PHI, PLI, and PERI. The findings indicate that plastic pollution, primarily from recreational activities, is prevalent in the beach sediment and water of the places investigated. It can be concluded that sediment is more heavily polluted with MPs than water. Planning pertinent MP toxicology-related research and bridging the gap between field and laboratory evaluations of possible ecological danger depend on the precise measurement of MPs and the types of polymers they include. The most dangerous chemicals and possibly some polymers could be replaced and their risks reduced, or they could be phased out as part of a solution for a more sustainable use of plastics [23].

Conclusion

The abundance of MPs with various polymer compositions in the water and sediments is polluting the seafood and may be causing the spread of harmful substances to people. In this study the distribution and ecological risk of MPs was investigated in the water and sediment of six sites in the coastlines of Tuticorin under two categories namely fishing sites and recreational sites. The results reveal that MP pollution originates from land-based activities. The sediments show comparatively higher concentration of MPs than that of water. The highest abundance of

MP pollution is found in Tiruchendur, which is due to the intensive tourism and pilgrimage activities, followed by Manapad and Muthunagar Beach, which is also due to high occurrence of recreational activities. Kayalpattinam is also famous for tourism but it shows comparatively lesser degree of MP pollution. Development of bio-based raw materials and biodegradable materials, reduced use, material reduction, eco design for recyclability, increased recycling, and international action and measures to reduce littering are possible solutions to lower the coastal MP pollution levels. There is a lack of knowledge on the polymer risk and ecological risk assessment of MPs in water. In the assessment of the ecological risk, we used all the MP data reported for the sediments along the Indian coast. PHI levels of MPs in water and sediment show a hazard to the ecosystem overall. Due to the presence of high-hazard score polymers like PA and PS, Tiruchendur, Manapad, and Muthunagar Beach have high PHI values (> 1000). PLI findings show that the water and sediments of the recreational locations have fair amounts of MPs, while the sediment of the fishing sites has less MP prevalence. To protect the health of the ecosystems and people, rigorous restrictions for the disposal of plastic waste should be imposed. We recommend that authorities and conservation managers take into account the ecological danger of MPs along the Indian coast.

References

[1] Europe, P. (2020). Plastics–the facts 2020. PlasticEurope, 1, 1-64.

[2] Gomiero, A., Strafella, P., & Fabi, G. (2018). From macroplastic to microplastic litter: occurrence, composition, source identification and interaction with aquatic organisms. Experiences from the Adriatic Sea. In Plastics in the Environment. Intech Open. https://doi.org/10.5772/intechopen.81534

[3] Gewert, B., Plassmann, M. M., & MacLeod, M. (2015). Pathways for degradation of plastic polymers floating in the marine environment. Environmental science: processes & impacts, 17(9), 1513-1521. https://doi.org/10.1039/C5EM00207A

[4] Strungaru, S.A., Jijie, R., Nicoara, M., Plavan, G., & Faggio, C. (2019). Micro-(nano) plastics in freshwater ecosystems: abundance, toxicological impact and quantification methodology. TrAC trends in analytical chemistry, 110, 116-128. https://doi.org/10.1016/j.trac.2018.10.025

[5] Guzzetti, E., Sureda, A., Tejada, S., & Faggio, C. (2018). Microplastic in marine organism: Environmental and toxicological effects. Environmental toxicology and pharmacology, 64, 164-171. https://doi.org/10.1016/j.etap.2018.10.009

[6] A.M., Kubowicz, S., Beegle-Krause, C., Skancke, J., Nordam, T., Landsem, E., Throne-Holst, M., & Jahren, S. Microplastic in global and Norwegian Marine Environments: Distributions, Degradation Mechanisms and Transport, 2017. Vol. M-918.

[7] Koehler, A., Anderson, A., Andrady, A., Arthur, C., Baker, J., Bouwman, H., Gall, S., Hidalgo-Ruz, V., Koehler, A., Law, K., Leslie, H., Kershaw, P., Pahl, S., Potemra, J., Ryan, P., Joon Shim, W., Thompson, R., Takada, H., Turra, A., & Wyles, K. (2015).

Sources, fate and effects of microplastics in the marine environment: A global assessment.

[8] Peixoto, D., Pinheiro, C., Amorim, J., Oliva-Teles, L., Guilhermino, L., & Vieira, M. N. (2019). Microplastic pollution in commercial salt for human consumption: A review. Estuarine, Coastal and Shelf Science, 219, 161-168. https://doi.org/10.1016/j.ecss.2019.02.018

[9] Shim, W.J., Hong, S.H., & Eo, S. (2018). Marine microplastics: abundance, distribution, and composition. In Microplastic contamination in aquatic environments (pp. 1-26). Elsevier. https://doi.org/10.1016/B978-0-12-813747-5.00001-1.

[10] Weinstein, J.E., Crocker, B.K., & Gray, A.D. (2016). From macroplastic to microplastic: Degradation of high-density polyethylene, polypropylene, and polystyrene in a salt marsh habitat. Environmental Toxicology and Chemistry, 35(7), 1632-1640. https://doi.org/10.1002/etc.3432

[11] Moore, C.J. (2008). Synthetic polymers in the marine environment: a rapidly increasing, long-term threat. Environmental research, 108(2), 131-139. https://doi.org/10.1016/j.envres.2008.07.025

[12] do Sul, J. A. I., & Jang, M. F. (2014). The present and future of microplastic pollution in the marine environment. Environmental pollution, 185, 352-364. https://doi.org/10.1016/j.envpol.2013.10.036

[13] Ryan, P.G., Moore, C.J., Van Franeker, J.A., & Moloney, C.L. (2009). Monitoring the abundance of plastic debris in the marine environment. Philosophical Transactions of the Royal Society B: Biological Sciences, 364(1526), 1999-2012. https://doi.org/10.1098/rstb.2008.0207

[14] Gregory, M.R., Andrady, A.L. (2003). Plastics in the marine environment. Plastics and the Environment, 379-401. https://doi.org/10.1002/0471721557.ch10

[15] Ng, K.L., & Obbard, J.P. (2006). Prevalence of microplastics in Singapore's coastal marine environment. Marine pollution bulletin, 52(7), 761-767. https://doi.org/10.1016/j.marpolbul.2005.11.017

[16] Barnes, D.K., Galgani, F., Thompson, R.C., & Barlaz, M. (2009). Accumulation and fragmentation of plastic debris in global environments. Philosophical transactions of the royal society B: biological sciences, 364(1526), 1985-1998. https://doi.org/10.1098/rstb.2008.0205

[17] Andrady, A.L. (2011). Microplastics in the marine environment. Mar Pollute Bull 62 (8): 1596–1605. https://doi.org/10.1016/j.marpolbul.2011.05.030

[18] Welden, N.A., & Lusher, A. (2020). Microplastics: from origin to impacts. In Plastic waste and recycling (pp. 223-249). Academic Press. https://doi.org/10.1016/j.marpolbul.2011.05.030

[19] Woodall, L. C., Sanchez-Vidal, A., Canals, M., Paterson, G. L., Coppock, R., Sleight, V., & Thompson, R. C. (2014). The deep sea is a major sink for microplastic debris. Royal Society open science, 1(4), 140317.

[20] Sathish, M.N., Jeyasanta, K.I., & Patterson, J. (2020). Monitoring of microplastics in the clam Donax cuneatus and its habitat in Tuticorin coast of Gulf of Mannar (GoM), India. Environmental Pollution, 266, 115219. https://doi.org/10.1016/j.envpol.2020.115219.

[21] De Witte, B., Devriese, L., Bekaert, K., Hoffman, S., Vandermeersch, G., Cooreman, K., & Robbens, J. (2014). Quality assessment of the blue mussel (Mytilus edulis): Comparison between commercial and wild types. Marine pollution bulletin, 85(1), 146-155. https://doi.org/10.1016/j.marpolbul.2014.06.006

[22] Li, J., Yang, D., Li, L., Jabeen, K., & Shi, H. (2015). Microplastics in commercial bivalves from China. Environmental pollution, 207, 190-195. https://doi.org/10.1016/j.envpol.2015.09.018

[23] Lithner, D., Larsson, A., & Dave, G. (2011). Environmental and health hazard ranking and assessment of plastic polymers based on chemical composition. Science of the total environment, 409(18), 3309-3324. https://doi.org/10.1016/j.scitotenv.2011.04.038

[24] Xu, P., Peng, G., Su, L., Gao, Y., Gao, L., & Li, D. (2018). Microplastic risk assessment in surface waters: A case study in the Changjiang Estuary, China. Marine pollution bulletin, 133, 647-654. https://doi.org/10.1016/j.marpolbul.2018.06.020

[25] Tomlinson, S. (2014). The politics of race, class and special education: The selected works of Sally Tomlinson. Routledge. https://doi.org/10.4324/9781315794785

[26] Peng, G., Xu, P., Zhu, B., Bai, M., & Li, D. (2018). Microplastics in freshwater river sediments in Shanghai, China: a case study of risk assessment in mega-cities. Environmental Pollution, 234, 448-456. https://doi.org/10.1016/j.envpol.2017.11.034

[27] Amelineau, F., Bonnet, D., Heitz, O., Mortreux, V., Harding, A.M., Karnovsky, N., Walkusz, W., Fort, J., Gremillet, D. (2016). Microplastic pollution in the Greenland Sea: Background levels and selective contamination of planktivorous diving seabirds. Environmental Pollution, *219*, 1131-1139. https://doi.org/10.1016/j.envpol.2016.09.017

[28] Moore, C.J., Moore, S.L., Leecaster, M.K., & Weisberg, S.B. (2001). A comparison of plastic and plankton in the North Pacific central gyre. Marine pollution bulletin, 42(12), 1297-1300. https://doi.org/10.1016/S0025-326X(01)00114-X

[29] Wright, S. L., Thompson, R. C., & Galloway, T. S. (2013). The physical impacts of microplastics on marine organisms: a review. Environmental pollution, 178, 483-492. https://doi.org/10.1016/j.envpol.2013.02.031 .

[30] Grover, A., Gupta, A., Chandra, S., Kumari, A., & Khurana, S. M. (2015). Polythene and environment. International Journal of Environmental Sciences, 5(6), 1091-1105.

[31] Botterell, Z.L., Beaumont, N., Dorrington, T., Steinke, M., Thompson, R.C., & Lindeque, P.K. (2019). Bioavailability and effects of microplastics on marine zooplankton: A review. Environmental Pollution, 245, 98-110. https://doi.org/10.1016/j.envpol.2018.10.065

[32] Li, J., Lusher, A., Rotchell, J.M., Company, S.D., Turra, A., Bråtec, I.L.N., Sun, C., Hossain, M.S., Li, Q., Kolandhasamy, P., Shi, H., (2019). Using mussel as a global bioindicator of coastal microplastic pollution. Environmental pollution, 244, 522-533. https://doi.org/10.1016/j.envpol.2018.10.032

[33] Cho, Y., Shim, W.J., Jang, M., Han, G.M., & Hong, S.H. (2019). Abundance and characteristics of microplastics in market bivalves from South Korea. Environmental pollution, 245, 1107-1116. https://doi.org/10.1016/j.envpol.2018.10.032

[34] Devriese, L. I., Van der Meulen, M. D., Maes, T., Bekaert, K., Paul-Pont, I., Frère, L., Johan, R., & Vethaak, A. D. (2015). Microplastic contamination in brown shrimp (Crangon crangon, Linnaeus 1758) from coastal waters of the Southern North Sea and Channel area. Marine pollution bulletin, 98(1-2), 179-187. https://doi.org/10.1016/j.marpolbul.2015.06.051

[35] Hall, N. M., Berry, K. L. E., Rintoul, L., & Hoogenboom, M. O. (2015). Microplastic ingestion by scleractinian corals. Marine Biology, 162(3), 725-732. https://doi.org/10.1016/j.marpolbul.2015.06.051

[36] Ory, N., Chagnon, C., Felix, F., Fernández, C., Ferreira, J. L., Gallardo, C., & Thiel, M. (2018). Low prevalence of microplastic contamination in planktivorous fish species from the southeast Pacific Ocean. Marine Pollution Bulletin, 127, 211-216. https://doi.org/10.1016/j.marpolbul.2017.12.016

[37] Zhao, S., Zhu, L., & Li, D. (2016). Microscopic anthropogenic litter in terrestrial birds from Shanghai, China: Not only plastics but also natural fibers. Science of the Total Environment, 550, 1110-1115. https://doi.org/10.1016/j.scitotenv.2016.01.112

[38] Crawford, C. B., & Quinn, B. (2016). Microplastic pollutants. Elsevier Limited.

[39] Cole, M., Lindeque, P., Fileman, E., Halsband, C., & Galloway, T.S. (2015). The impact of polystyrene microplastics on feeding, function and fecundity in the marine copepod Calanus helgolandicus. Environmental science & technology, 49(2), 1130-1137. https://doi.org/10.1021/es504525u

[40] Savoca, S., Capillo, G., Mancuso, M., Bottari, T., Crupi, R., Branca, C., & Spanò, N. (2019). Microplastics occurrence in the Tyrrhenian waters and in the gastrointestinal tract of two congener species of seabreams. Environmental Toxicology and Pharmacology, 67, 35-41. https://doi.org/10.1016/j.etap.2019.01.011

[41] Jang, M., Shim, W.J., Cho, Y., Han, G.M., Song, Y.K., Hong, S.H., 2020. A close relationship between microplastic contamination and coastal area use pattern. Water Res. 171, 115400. https://doi.org/10.1016/j.watres.2019.115400

[42] Pan, Z., Liu, Q., Jiang, R., Li, W., Sun, X., Lin, H., & Huang, H. (2021). Microplastic pollution and ecological risk assessment in an estuarine environment: The Dongshan Bay of China. Chemosphere, 262, 127876. https://doi.org/10.1016/j.chemosphere.2020.127876

[43] Li, R., Yu, L., Chai, M., Wu, H., & Zhu, X. (2020). The distribution, characteristics and ecological risks of microplastics in the mangroves of Southern China. Science of the Total Environment, 708, 135025. https://doi.org/10.1016/j.scitotenv.2019.135025

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