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Research Article

Distribution and Abundance of Micro Litters in the Selected Beaches of Gulf of Mannar, India during August 2013 and February 2014

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Abstract

Anthropogenic, non-degradable materials are well-known for fragmentation in the coastal and marine environments which lead to formation of micro litter particles. Due to the buoyant and persistent properties of micro litters, they have a potential to become widely dispersed in the coastal marine environment through the hydrodynamic processes and ocean currents. Ingestion of these micro litters in marine organisms has been reported hence they play a vital role in disturbances in the marine food webs. Therefore, we have assessed the distribution and abundance of micro litters in ten selected beaches along the Gulf of Mannar between Dhanuskodi and Thoothukudi, southeast coast of India during August 2013 and February 2014.

Overall, the total micro litters segregated in the Gulf of Mannar were 27.9 item $m^{3\ -1}$. The sampling period wise record showed that August 2013 found highest record of 17.67 item $m^{3\ -1}$ while it was only 10.23 item $m^{3\ -1}$ in Feb. 2014. Overall Gulf of Mannar recorded >92.6% occurrences of both hard (40.5%) and soft (52.1%) plastic type micro litters, whereas no single record of litter types of glass and cloth type micro litters were noticed. Nevertheless, overall, 2.6-5.0 mm size groups accounted maximum numbers in the Gulf of Mannar beaches. As litter groups, overall mean abundance of all five micro litter categories were higher in Mugundarayar Chadram beach (17.0%) in Aug. 2013 and in Kundukal (15.2%) during Feb. 2014. As micro litter size categories, >10 mm sizes found to be dominated (1.56 item $m^{3\ -1}$) in Muguntharayar Chadram beach and Pudumadam beach during Aug. 2013 and Feb. 2014, respectively.

The present study concludes that, the abundance of micro litters found to be varied between surveys, beaches, litters' group and litters' sizes. The micro litters of soft (SP) and hard plastics (HP) contributed more than 92.6% and mostly by fragments of fishing nets, nylon ropes, food wrappers, plastic buoys etc. The present study concludes that there is a possibility of migration of micro litters to the coastal and coral reef environments of Gulf of Mannar due to hydrodynamic process thus enter the marine food chain including corals via engulfment as food materials. Therefore, a proper disposal plan should be followed to control solid waste management in the Coastal Marine Environment.

Keywords: Marine Litter; Micro Plastics; Beaches; Hydrodynamic process; Gulf of Mannar

Introduction

Marine liter is defined as "any manufactured or processed solid waste material (typically inert) that enters the marine environment from any source". The oceans of the world were considered as boundless reservoir of productivity and a massive sink with unlimited capacity to assimilate wastes (Coe et al, 1997). Enormous quantities of man-made waste materials are being dumped into the oceans

which include debris and litter which are not easily biodegradable. A large part of the world population is using the open environment as low-cost disposal, alternative for solid wastes (Anbumani and Kakkar, 2018). This is particularly true in India. Persistent synthetic materials such as plastics have a wide variety of human needs and applications.

The oceans of the world are mostly polluted by different types of litter thrown in the beaches, particularly plastics (UNEP, 2009). Macro litters such as domestic litter, uncovered landfills, dumping of waste containers, agricultural plastics, wastewater effluents and overflows, rivers, various human (recreational) activities in the coastal zones, emissions of plastic debris enter the sea through land-based sources (Ryan et. al., 2009; Rech et al., 2014; Sadri and Thompson, 2014), and emissions during transport of plastic products (Bowmer and Kershaw, 2010; UNEP, 2009).

As per the recent estimate, the production of plastic materials has been increased 300 million tonnes (PlasticEurope, 2015). In 2010, almost 4.8 to 12.7 million tones of plastic litters entered the ocean (Jambeck et al., 2015). Worldwide the plastic litter pollution is contributed higher proportion compared with other litters because of low degradation rate, buoyancy and long-range surface transport by way of ocean currents and surface winds (Cozar et al., 2015; Perez-Venegas et al., 2017). As reported by Topçu et al. (2013) and Thiel et al., (2013) more than 80% litters in the beaches were contributed by plastic bags, fishing equipment, food and beverage containers.

Most of the plastic materials float and are durable over time scales of months to years to decades (Hinojosa and Thiel, 2009; Lavender Law et al., 2010; Proskurowski et al., 2010; Andrady, 2011). They were transported by wind, water current, gravity, and human and animal activities to temporary or permanent sinks of the environment. The litter gets accumulated in the shorelines, estuaries and on the seafloor (Andrady, 2011). Unless large-scale efforts to control it are taken, marine debris problem will get progressively worse in future.

The micro litters to the marine and coastal environments originate from two main sources such as direct introduction with runoff and weathering breakdown of meso- and macro plastic debris. The micro- and nano-particles of plastics as consumer products (Maynard, 2006) are directly entered via runoff into the oceans (Gregory, 1996; Fendall and Sewell, 2009).

The macro litters like plastics, rubbers and related debris fragmented as smaller particles by abiotic factors such as UV radiation and continuous sunlight which contaminate the coastal marine environments in the bottom as well as mid-water column of the Ocean (Andrady, 2011; Thompson et al., 2004; Cole et al., 2011) or through animal digestion (Van Franeker et al., 2011). Very tiny micro litters settled in the beach sand thus we need different methodology for assessment of size and nature (Leslie et al., 2011; Arthur et al., 2009). It was reported that the soft type micro plastic caused necrosis in cold water corals (Fabri et al., 2014).

Marine environment all over the world are contaminated by marine litters mainly plastics while there is growing concern about tiny plastic fragments known as micro plastics. Micro plastics are part of the overall marine litter issues, which is attracting attention not only from national and international authorities, but also NGOs, the media, scientists, consumers, artists, the plastics industry and others (EPA, 2011; Leslie et al., 2011; Thevenon et al., 2014) about the impact of plastic ingested marine species and the accumulation of plastics in the coastal and remote areas of the oceans. They reported that the micro plastic materials have been defined by the international scientific community as synthetic polymer particles <5 mm' in diameter.

The extensive use of micro litters of scrub beads as abrasives in personal care products has also been identified as potential contributor to marine pollution (Fendall and Sewell, 2009). However, these micro litter particles of size <1 mm may be a major source of microplastic pollution to the aquatic environments, because they are designed to be washed down the drain and they are usually not captured by treatment screens in wastewater plants (generally larger than 1 to 6 mm).

The researchers have defined the term 'micro-plastics' and 'micro-litter' by differently. Gregory and Andrady (2003) defined micro litter as the barely visible particles that pass through a 500 µm sieve but retained by a 67 µm sieve (0.06–0.5 mm in diameter). Though the particles larger than this were called as 'meso-litter'. On the other hand, Betts, (2008) and Fendall and Sewell, (2009) have also defined that the litter particle size <5 mm was called as 'micro litter'. Litter particles of size 5 mm are mostly present in sea water (Ng

and Obbard, 2006; Barnes et al., 2009).

For the past two decades, more research on micro litter pollution including plastic litters were carried out and a significant finding stated that very smaller fragments of micro litters distributed in the oceans worldwide (Barnes et al., 2009) including even in Antarctica (Zarfl and Matthies, 2010). According to Hidalgo-Ruz and Thiel, (2013), the plastic debris accumulation in the remote coastal coral islands was higher compared to continental coastal regions due to wave action. These man-made micro litter particles have been accumulating in the beaches, coastal and marine environments for the past four decades (Thompson et al., 2004). Some portion that ends up in the marine waters is considered as a major global problem (UNEP, 2011).

Marine Protected areas (MPA) are coming under high attention of Environmentalist in case of marine litter. Marine litter can spread very easily to the coastline because of marine transport, tourism, and uncontrolled discharge of municipal waste in illegal landfills. Marine litter has become a serious pollution problem in all coastal regions including the Gulf of Mannar (Robin et al., 2020). The impact is very serious and multidimensional. It can cause serious environmental problem with possible transfer of toxic chemical substances to the marine habitats. Marine litter threatens marine biota through entanglement, suffocation (fish, seabirds, and other marine animals) and ingestion (Laist, 1997). In addition, marine litter poses a risk to human health. Another dimension of marine litter is economic, because of polluting recreational coasts, gulfs and coastlines that attract tourists and apart from an aesthetic problem can cause damage to the quality of swimming water and the sea habitats and their biodiversity.

The marine litter assessment study in India was began after 2010. Very limited studies were carried out the assessment of macro litters along the beaches of Indian coasts (Jayasiri et al., 2013; Ramakritinan et al., 2015; Ramakritinan and Kumaraguru, 2016; Kaladharan et al., 2017; Krishnakumar et al., 2018; Naidu, 2019; Sulochanan et al., 2019). As such the distribution of micro litters in the beaches of India especially Gulf of Mannar coast is very scarce (Ramakritinan and Kumaraguru, 2016; Veerasingam et al., 2016; Karthik et al., 2018; Kumar et al., 2016, 2018; Naidu, 2019; Sulochanan et al., 2019; Robin et al., 2020; Mugilarasan et al., 2021). This type of investigation is especially of great concern, now, because the Gulf of Mannar marine environment with the chain of 21 islands is a Marine Biosphere Reserve with a Marine National Park hence bioaccumulation of micro litters in the marine organisms via food chain create severe impacts on biodiversity. Therefore, we aimed to assess the distribution and abundance of marine micro litters (types and size categories) of ten selected beaches of Gulf of Mannar, Southeast coast of India during August 2013 and February 2014 and to recommend ways to mitigate further problems.

Materials and Methods

Preparation of Litter Classification and assessment

For land-based assessment, a general assessment along the coastal region of Gulf of Mannar between Dhanushkodi and Thoothukudi was conducted to identify the study site/location. As per the standard protocol, the assessment locations were selected based on the following criteria such as stations should not contaminated by coast goers; should not subjected to periodic cleaning; should not exhibiting a steep slope; should not in the vicinity of rivers; should have homogenous sedimentology and should locate windward and open to the sea.

For the field assessment, a well-documented Litter Classification sheet required for the identification of micro litters in the beaches was prepared based on the methodology adapted by Cheshire and Westphalen (2007) and Cheshire et al, (2009) with minor changes in the litter types (Ramakritinan and Kumaraguru, 2016). In the present study, the protocol was standardized from the land-based litter assessment methodologies.

During this survey, the coastal villages/towns were visited and taken photographs to know the current status of litters along the coastal region of Gulf of Mannar. After the complete survey, ten beaches along the Gulf of Mannar, India such as Mugundarayar Chadram (MCM), Kundukal (KKL), Mandapam (MDM), Pudumadam (PDM), Therku Pudukudiyiruppu (TPK) near Periapattinam, Bharathi Nagar (BNR) near Keezhakarai, Chinna Ervadi (CEI), Valinokam (VNM), Vembar (VBR) and Thoothukudi (TTK) were selected for marine

micro litter assessment (Figure 1). The GPS co-ordinates of the survey locations were marked using GARMIN GPSMAP78sc (Table 1). The micro litter assessments were conducted during the months August, 2013 and February, 2014.

Figure 1: Map of Study sites for micro litter distribution along the Gulf of Mannar between Dhanuskodi and Thoothikudi, Southeast coast of India.

S. No.	*Selected Coastal Towns / Villages*	*Coordinates*
1.	Mugundaraya Chadram (Dhanuskodi)	N 09º11.960' E 079º22.879'
2.	Kundukal	N 09º15.449' E 079º13.282'
3.	Mandapam	N 09º16.675' E 079º09.088'
4.	Pudumadam	N 09º16.313' E 079º00.073'
5.	Therku Puthu Kudiyiruppu (Periapattinam)	N 09º15.029' E 078º54.199'
6.	Bharathi Nagar (Keezhakkarai)	N 09º13.104' E 078º45.622'
7.	Chinna Ervadi	N 09º11.660' E 078º43.158'
8.	Valinokam	N 09º09.680' E 078º22.063'
9.	Vembar	N 09º04.482' E 078º22.063'
10.	Thoothukudi	N 08º45.182' E 078º11.490'

Table 1: Sleeted study sites and GPS Coordinates for marine micro litter assessment along the Gulf of Mannar, Southeast coast of India.

Micro litter Assessment

In the present micro litter assessment study, five different types of marine litters such as hard plastics (HP), soft plastics (SP), foam (FM), glass (GL) and cloth (CL) as well as five different size categories such as <1, 1.1-2.5, 2.6-5, 5.1-10 and >10 mm were selected based on the preliminary surveys conducted (Ramakritinan and Kumaraguru, 2016). As per the International Scientific Community definition, < 5mm size is considered as micro litter (Leslie et al., 2011; Arthur et al., 2009; Hidalgo-Ruz et. al, 2012) however, the present investigation included > 5 to 10mm sizes also considered as 'micro litter'.

The sample processing methods were distinguished in four ways viz., density separation, filtration, sieving and visual sorting of micro plastics. In the present study the samplings were done in high tide marks of the selected ten beaches using quadrate i.e., 40 x 40 x 5 cm (L x W x H) made on steel plate (Figure 2). Totally nine sampling was done in each location. The total area of the quadrate per sampling was 0.8 m^3 and the results were calculated for m^3. The collected samples in each quadrate were separately dissolved in water in the ratio of 1:3. Then the sediment was allowed to settle for 60 minutes, then the supernatant was poured through a 1000,

500, 250, and 100 µm mesh sieves (Figure 2). For each sample, the extraction was performed in triplicate and the collected smaller sized particles (sieve) were examined under a binocular microscope with stage micrometer. After observation, the micro litters were separated by Litter types (Table 2) and Litter size categories of micro litters. The mean and percentage distribution of marine micro litters as groups and size categories were calculated using Excel.

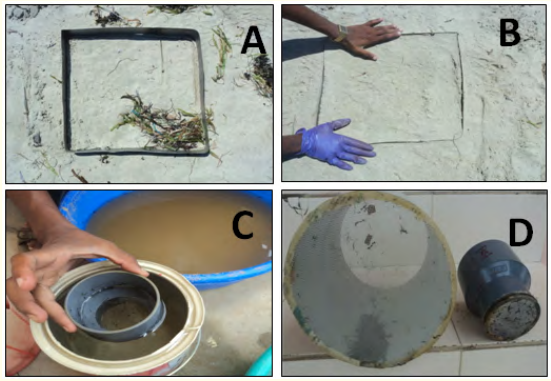

Figure 2: Marine Micro Litter sampling and processing methodology: (A) Metal Quadrate designed for micro litter sampling (Size: 40cm L x 40cm W x 5cm H); (B) Micro litter sampling procedure with metal quadrate, (C) Segregation of micro litter particles with specialized sieves, (D) PVC Sieves designed for micro litter analysis.

Group	*Litter type*
1.Hard Plastic	Plastic bottles, drums, cans, buckets, trays; Spoons, forks, knives; Bottle caps & lids; Plastic buoys; Fishing lures; Toothbrushes and hair brushes; Fishing traps and pots, PVC Pipes
2. Soft Plastic	Plastic bags, Food wrappers, Palette wrapper, Strapping, Plastic Rope, Fishing net, Monofilament line, Disposable nappies, Drinking straws, Polypropylene tarpaulin, Plastic sheet
3. Glass	Alcoholic drink bottles, Medicine bottles, Food & Beverage bottles, Table wares, Light globes, fluorescent light tubes, Glass buoys
4. Foam	Cups or food trays, Packaging foam, Insulation foam Foam buoys
5. Cloth	Sanitary ware, Clothing, Rags, Sailcloth, Bags, Canvas, Hats

Table 2: Types of Marine Litter Classified as described by Cheshire and Westphalen (2007) & Cheshire and Adler (2009) with minor modifications (Ramakritinan & Kumaraguru, 2016).

Results

Tables 3 and 4 shows the mean distribution of micro litters as groups and sizes (item $m^{3\,-1}$; n=9) segregated in ten selected beaches along the Gulf of Mannar, India during the months of August, 2013 and February, 2014. Overall, the total items of micro litters segregated in the beaches of Gulf of Mannar were 27.9 item $m^{3\,-1}$, of these, 17.67 item $m^{3\,-1}$ in Aug. 2013 and 10.23 item $m^{3\,-1}$ in Feb. 2014 were accounted overall Gulf of Mannar beaches (Tables 3 & 4). As micro litter groups, only HP, SP and FM types were reported in all ten surveyed beaches while no report on GL and CL types. Overall, SP types observed maximum abundance of 52.12% followed by HP and the least of FM types (Figure 3). In Aug. 2013, the HP type showed highest abundance of 63.6% followed by SP types (27.0%) and the least occurrences in FM types i.e., 9.4% however, in Feb. 2014, the SP types exhibited highest abundance of 77.2% followed by HP types (17.4%) and the least one of FM types (5.4%) (Figure 4). The present study states that the plastic type micro litters found to be

highest record overall in the Gulf of Mannar beaches.

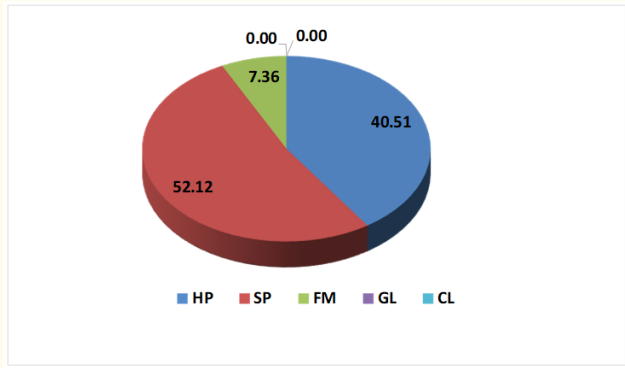

Figure 3: Overall abundance of Micro Litter types in the Gulf of Mannar beaches south-east coat of India during the whole study periods (n = 9).

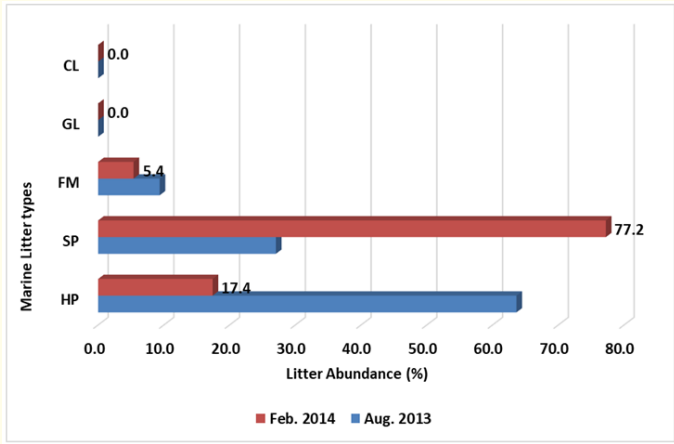

Figure 4: Overall abundance of Micro Litter types segregated in ten selected beaches of Gulf of Mannar, Southeast Coast of India during Aug. 2013 and Feb. 2014 (n=9).

Similar to micro litter groups, the overall litters segregated based on sizes showed that 2.5-5.0 mm sizes reported maximum abundance (30.1%) and least of 5% in < 1.0 mm size categories (Figure 5). In Aug. 2013, the highest distribution of 30.8% in 2.6–5.0 mm size categories and the least of 1.3% in < 1.0 mm size categories were noticed in all ten sampled beaches. Though in Feb. 2014, both 1.1-2.5 mm and 2.6-5.0 mm size categories noticed highest abundance and it was 29.4% (Figure 6) while micro litter count was least in < 1.0 mm size categories. The above results clearly reveal that the 1.1 mm to 5.0 mm size categories noticed highest record in the Gulf of Mannar beaches while, there were variations in micro litter occurrences between the beaches. Among the beaches, overall highest occurrences were reported in MCM and KKL beaches (13.9%) and it was lowest in VBR beach (Figure 7). The survey wise segregation data showed that the MCM beach noticed highest abundance (17.0%) and VBR beach noticed least distribution (3.7%) in Aug. 2013 and, in Feb. 2014, the respective occurrence was 15.2% in KKL beach and 5.5% in BNR beach (Figure 8).

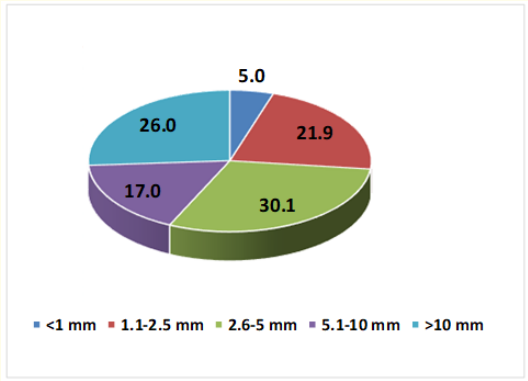

Figure 5: Overall occurrence of Micro Litter Size categories in the Gulf of Mannar beaches southeast coat of India during the whole study periods (n=9).

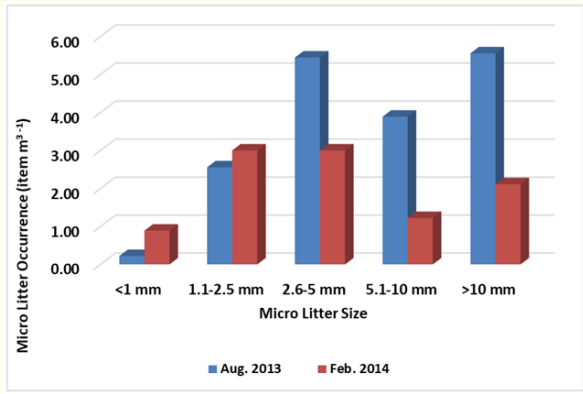

Figure 6: Overall occurrence of Micro Litter Size categories segregated in ten selected beaches of Gulf of Mannar, Southeast Coast of India during Aug. 2013 and Feb. 2014 (n=9).

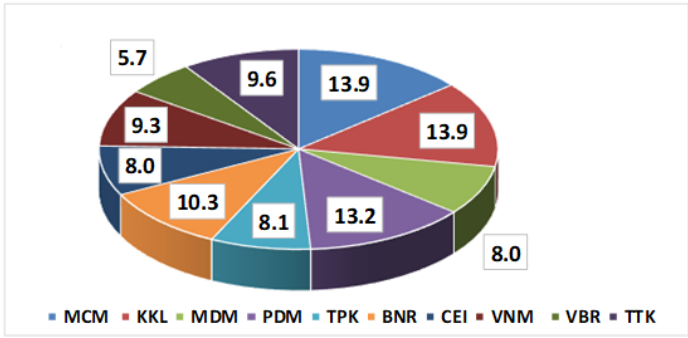

Figure 7: Overall abundance of micro litters segregated in ten selected beaches in the Gulf of Mannar, Southeast coast of India (n=9).

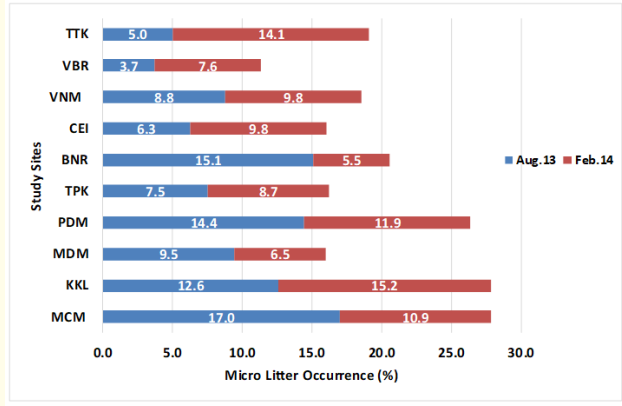

Figure 8: Abundances of Micro Litter Types segregated in ten selected beaches of Gulf of Mannar, Southeast Coast of India during Aug. 2013 and Feb. 2014 (n=9).

Table 3 describes the distribution of micro litter based on types in the ten beaches along the Gulf of Mannar coast, India. During the survey periods, there were no record of Glass (GL) and Cloth (CL) type micro litters in all ten beaches of Gulf of Mannar. Totally, in Aug. 2013, the HP types were dominated by 11.23 item m^{3-1} followed by SP types 4.77 item m^{3-1} while in Feb. 2014, only the SP type litters were dominated by 7.9 item m^{3-1} followed by HP types. The above results reveal that overall, the litter abundance was higher in Aug. 2013 than that of Feb. 2014.

The beach wise abundance of micro litter types was differed between the survey period. The beach wise data exhibited HP type (2.0 item m^{3-1}) was a dominant micro litter in MCM beach during Aug. 2013 however, in Feb. 2014, PDM beach recorded maximum count of HP type (0.78 item m^{3-1}). In Aug. 2013 survey, the SP types recorded highest in the three beaches such as MCM, KKL and PDM (each 0.89 item m^{3-1}), though, this type was highest of 1.56 item m^{3-1} in KKL beach. The FM type of litters exhibited highest count in VNM and CEI beaches (0.44 and 0.33 item m^{3-1} respectively) (Table 3).

Beaches	*August, 2013*						*February, 2014*					
	HP	*SP*	*FM*	*GL*	*CL*	*Total*	*HP*	*SP*	*FM*	*GL*	*CL*	*Total*
MCM	2.00	0.89	0.11	0.00	0.00	3.00	0.33	0.78	0.00	0.00	0.00	1.11
KKL	1.11	0.89	0.22	0.00	0.00	2.22	0.00	1.56	0.00	0.00	0.00	1.56
MDM	1.56	0.11	0.00	0.00	0.00	1.67	0.00	0.56	0.11	0.00	0.00	0.67
PDM	1.44	0.89	0.22	0.00	0.00	2.55	0.78	0.33	0.11	0.00	0.00	1.22
TPK	0.67	0.44	0.22	0.00	0.00	1.33	0.67	0.22	0.00	0.00	0.00	0.89
BNR	1.78	0.78	0.11	0.00	0.00	2.67	0.00	0.56	0.00	0.00	0.00	0.56
CEI	0.56	0.22	0.33	0.00	0.00	1.11	0.00	0.67	0.33	0.00	0.00	1.00
VNM	1.11	0.00	0.44	0.00	0.00	1.55	0.00	1.00	0.00	0.00	0.00	1.00
VBR	0.33	0.33	0.00	0.00	0.00	0.66	0.00	0.78	0.00	0.00	0.00	0.78
TTK	0.67	0.22	0.00	0.00	0.00	0.89	0.00	1.44	0.00	0.00	0.00	1.45
Total Items	11.23	4.77	1.65	0.00	0.00	17.65	1.78	7.90	0.55	0.00	0.00	10.24

Table 3: Mean distribution of micro litter types segregated per m^3 (n=9) during the months of August, 2013 and February, 2014 in ten selected beaches of Gulf of Mannar, Southeast coast of India.

Table 4 represents the abundance of micro litters based on size categories in the Gulf of Mannar, India during the months of Aug. 2013 and Feb. 2014. Of all five different sizes categorised during Aug. 2013, the highest count of 1.56 item m^{3-1} reported in >10mm size categories in MCM beach while the lowest abundance of 0.11 item m^{3-1} reported in all size groups in the beaches of MCM, MDM, TPK, VBR and TTK (Table 4).

Beaches	August, 2013						February, 2014					
	<1 mm	1.1-2.5 mm	2.6-5 mm	5.1-10 mm	>10 mm	Total	<1 mm	1.1-2.5 mm	2.6-5 mm	5.1-10 mm	>10 mm	Total
MCM	0.00	0.11	0.89	0.44	1.56	3.00	0.11	0.44	0.11	0.22	0.22	1.11
KKL	0.00	0.89	0.78	0.22	0.33	2.22	0.11	0.44	0.67	0.00	0.33	1.56
MDM	0.00	0.22	1.33	0.11	0.00	1.67	0.11	0.22	0.33	0.00	0.00	0.67
PDM	0.00	0.56	0.56	0.89	0.56	2.56	0.22	0.00	0.00	0.11	0.89	1.22
TPK	0.11	0.11	0.00	0.22	0.89	1.33	0.22	0.00	0.33	0.00	0.33	0.89
BNR	0.00	0.56	0.78	0.89	0.44	2.67	0.00	0.11	0.33	0.11	0.00	0.56
CEI	0.00	0.00	0.00	0.33	0.78	1.11	0.00	0.22	0.22	0.44	0.11	1.00
VNM	0.00	0.00	0.56	0.33	0.67	1.56	0.11	0.78	0.00	0.11	0.00	1.00
VBR	0.00	0.00	0.11	0.44	0.11	0.67	0.00	0.22	0.33	0.11	0.11	0.78
TTK	0.11	0.11	0.44	0.00	0.22	0.89	0.00	0.56	0.67	0.11	0.11	1.44
Total Items	0.22	2.56	5.44	3.89	5.56	17.67	0.89	3.00	3.00	1.22	2.11	10.22

Table 4: Mean distribution of micro litter micro litter size categories segregated per m^3 (n=9) during the months of August, 2013 and February, 2014 in ten selected beaches of Gulf of Mannar, Southeast coast of India.

In each size category, the beaches of TPK and TTK observed micro litter of < 1mm size i.e., 0.11 item m^{3-1} through the remining beaches found no record. In the meanwhile, maximum record of 0.89 item m^{3-1} in 1.1-2.5 mm size were reported in KKL beach; 1.33 item m^{3-1} of 2.6-5.0 mm size in MDM beach; 0.89 item m^{3-1} of 5.0-10 mm size reported in PDM and PNR beaches (Table 4). Overall, the surveyed beaches exhibited nil or fewer abundance of smaller size categories like < 1mm besides the size group 1.1-2.5 mm recorded in most of the beaches of Gulf of Mannar (Table 4).

Discussion

Reports of plastic pollution in the ocean was first appeared in the scientific literature in the early 1970s (Carpenter et al., 1972; Carpenter and Smith, 1972; Colton and Knapp, 1974) yet more than 40 years later, no rigorous estimates exist the amount and origin of plastic debris entering the marine environment (Jambeck et al., 2015). Plastics have become increasingly dominant in the consumer market place since their commercial development in the 1930s and 1940s.

Plastic waste materials also end up in the marine environment when accidentally lost, carelessly handled (Wilber, 1987) or left behind by beachgoers (Pruter, 1987). They also reach the sea as litter carried by rivers and municipal drainage systems (Pruter, 1987; Williams and Simmons, 1997). There are major inputs of plastic litter from land-based sources in densely populated or industrialized areas (Pruter, 1987; Gregory, 1991), most in the form of packaging. Earlier systematic studies on marine micro and macro litter distribution along the beaches of Gulf of Mannar revealed that the major sources of marine litters were from local people, fisherfolk, tourists, recreation, municipal dumping and devotees while the distribution of litter groups was influenced by the sources (Ramakritinan and Kumaraguru, 2016). They reported that the contribution of marine litter pollution to most of the fishing villages in the Gulf of Mannar were due to fishing gears, plastics bags and other related groups; but the recreational, tourists and devotees' destinations showed

typically plastic bags of various sizes, plastic and glass bottles, cloths etc (Figure 9). Similar findings were described by Krishnakumar et al., (2018) in Nallathanni island, Gulf of Mannar; Mugilarasan et al., (2021) in Northeast beaches, West Bengal; Kaladharan et al., (2017) along the maritime States of Peninsular coast of India as well as the Union Territories of Andaman and Lakshadweep Islands.

Figure 9: Macro Litter contamination along the ten selected beaches of Gulf of Mannar, Tamil Nadu. (A) Mugundarayar Chadram (Dhanuskodi), (B) Kundukal (Pamban), (C) Mandapam, (D) Pudumadam, (E) Therkku Puthukudiyiruppu (Periyapattinam), (F) Bhrathi Nagar (Keezhakari), (G) Chinna Ervadi, (H) Valinokkam, (I) Vembar & (J) Thoothukudi (Ramakritinan & Kumaraguru, 2016).

The present investigation confirmed that most of the micro litters sampled in the Gulf of Mannar were hard plastics, soft plastic and foam types only and these litter groups contributed highest of 92.6% based on two-time sampling. Overall total abundance was 27.9 item $m^{3\,-1}$ (Figure 10). A study conducted by Robin et al., (2020) categorized 40.7 item $m^{3\,-1}$ in the beach sediments in Kerala coast as

one time sampling in 2018 and it was 1.5 times higher concentrations than that of Gulf of Mannar coast.

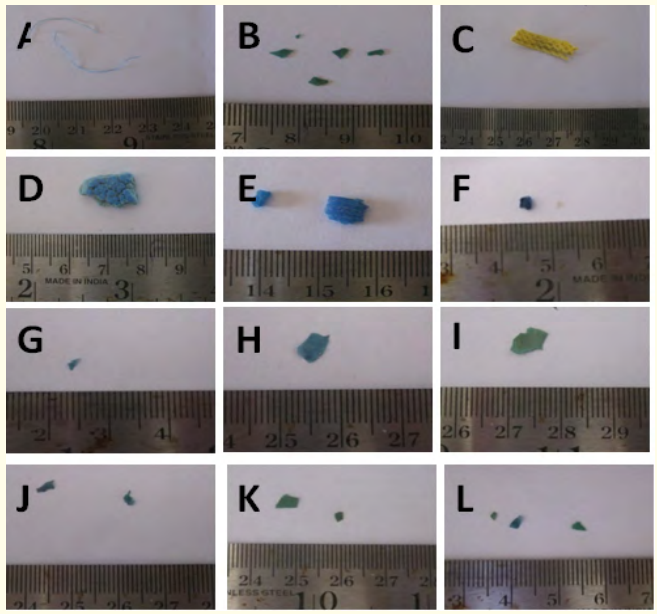

Figure 10: The major types of micro liters segregated in the beaches of Gulf of Mannar, India during the study periods: (A) SP- fishing net fragment; (B, D-L): HP- plastic fragments; (C): SP- packing material.

Likewise, Karthik et al., (2018) segregated micro plastic litters along the Tamil Nadu Coast in September 2017 and they accounted microplastic particles ranged between 9 and 178 item $m^{2\,-1}$ in the Hide Tide Limit and 2 and 64 item $m^{2\,-1}$ at the Low Tide Limit whereas our study was conducted only in the Gulf of Mannar beaches between Dhanuskodi and Thoothukudi. The variations in micro litter count might be due to quantity of litter wastes dumping in the coastal regions. They reported that the highest concentrations of micro plastic litters were noticed in closer to the river mouths like Ennore, Cooum, Adyar, Muttukadu, Puducherry, Cuddalore and Nagapattinam. It was supported by the findings of Rech et al., (2014) and Zhao et al., (2015). The current study results conclude that the abundance of micro litters in all ten beaches was ranged from 1.44 to 4.11 item $m^{3\,-1}$.

Further, the categorization of marine micro litters types with different size groups such as <1, 1.1-2.5, 2.6-5, 5.1-10.0 and > 10 mm were done in the current study. Overall mean abundances of all five micro litter categories segregated in Aug. 2013 and Feb. 2014 were higher in Mugundarayar Chadram (MCM) beach (17.0%) and in Kundukal (KKL) beach (15.2%) respectively. As micro litter sizes, >10 mm size groups found to be dominated both in Aug. 2013 and Feb. 2014 i.e., 1.5 item $m^{3\,-1}$ in Muguntharayar Chadram beach and 0.9 item $m^{3\,-1}$ in Pudumadam beach respectively. Between beaches, the higher abundance observed in both 2.6-5 mm and > 10 mm size groups during Aug. 2013 (5.5 item $m^{3\,-1}$), whereas in Feb. 2014, 1.1-2.5mm and 2.6-5 mm size groups noticed higher abundances (3.0 item $m^{3\,-1}$) comparably it was lower in abundance.

The micro litter assessment in four locations along the Mumbai coast for 12 months at an interval of 2 months conducted by Jeyasri et al., (2013) revealed that the total micro litter abundance recorded were 960 item $m^{3\,-1}$ and abundance was higher than that of present and other micro litter study conducted in the Indian beaches. A similar study carried out by Karthik et al., (2018) in the whole Tamil Nadu coast concluded that the size group between 2.36 and 4.75 mm contributed highest quantity by weight (86.5%) while a study in California coast by Moore et al. (2001) reported 1 and 2.8 mm size micro plastics to ~61% of total microplastics; in Hawaii, McDermid and McMullen (2004) identified sizes between 2.8 and 4.75 mm corresponding to ~48%; in Kerala coast, Robin et al., (2020) reported

higher abundance of 0.52 item m^{3-1} in 0.3 – 0.6 mm size micro litters (i.e., 41%) and in the North Atlantic Ocean, Moret-Ferguson et al. (2010) recorded highest of 69% in micro litter size between 2 – 6 mm. The above studies stated that the higher abundance of micro litter sizes varied with regions, riverine inputs, coastal population, local dumping, recreational activities etc.

The major types of micro liters observed during this study were broken pieces of plastics, fragments of fishing nets, lines, pieces of foam, bottle cap, cloths rubber chapels etc (Figure 10). Of these, broken pieces of nylon ropes, fragment of net, plastic materials and foam contributed higher accumulation in all study areas but these were maximum in the shores of Mugundarayar Chadram, Kundukal, Chinna Ervadi, Vembar and Thoothukudi. Mostly the marine litters on the shores of the Gulf of Mannar coast come from the fishermen, local inhabitants, tourists, and devotees (Ramakritinan and Kumaraguru, 2016) and they reached the coastal marine waters by way of ocean currents and surface winds (Cozar et al., 2015; Perez-Venegas et al., 2017).

The average quantity of plastics varies from 60 to 80% of total marine litters which can reach as much as ~95% of the total amount of marine litter (Derraik, 2002). Very small sized micro litters have larger surface area with a higher possibility of absorption of other pollutants are considered a bigger threat to marine organisms (Devriese et al., 2017). Thus, the worldwide use of micro plastic-containing products directly enters as microbeads via various sources to the coastal marine environment which can be consumed by planktonic and filter-feeding organisms at the base of the aquatic food chain including corals (Reichert et al., 2017). Anbumani & Kakkar (2018) elaborately reviewed the ecotoxicological effects of microplastics on biota and highlighted the effect of microplastics in organisms occupying different trophic levels under laboratory and in situ conditions, probable mechanism of its toxicity, and regulatory and policy framework followed by priority research areas. They suggested that microplastic accumulation and its associated adverse effects make it mandatory to go in for risk assessment and legislative action.

Conclusion

The present study concludes that mostly the micro litters of 1.1 to 5.0 mm sizes showed highest abundances in the Gulf of Mannar beaches and more than 92% contributed by plastic type micro litters. Therefore, the risk of ingestion of micro plastics to marine organisms is higher. Since the land-based sources are the major contributors of litter pollution to the costal marine environments, it is required continuous monitoring of macro litters / debris along the beaches, quantify the micro litters in the beaches, sediments and water columns and assess their bioaccumulation in the aquatic fauna. The present study evidenced that the solid waste management in the coastal beaches of Gulf of Mananr is very poor condition hence a proper municipal waste management plan is necessary to control the litter contamination and conduct frequent coastal cleanups programmes. To save the marine ecosystems of Gulf of Mannar including the fragile coral reef ecosystems from marine micro litter pollution, the government departments', educational institutions and NGOs should give environmental education.

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Conflict of Interest

The authors declare no conflict of Interest.

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