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Baseline

Assessment of plastic debris in remote islands of the Andaman and Nicobar Archipelago, India

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ABSTRACT

An attempt was made in during August 2018 to study the plastic debris present in beach sediments at the remote islands of the Andaman and Nicobar Archipelago, India. The maximum number of plastic debris was noticed in the North and Middle Andaman Island sector and the Nicobar Island sector. White, irregular shaped polyethylene and polypropylene debris were the predominant plastic varieties found in the study area. The plastic litters disposed in the marine environment could be carried away by currents, which then circulate around the island and finally reach the coastal areas of the Andaman and Nicobar Archipelago. The plastic litter was contributed from tourist, shipping activities and improper handling of solid wastes.

Floating marine debris pose a serious threat to the marine and freshwater environment, especially for the individuals organisms of the ecosystem (Thiel et al., 2003). Environmental pollutant monitoring studies are more important in terms of the discharged pollutants in the marine environment and the total affected surface area (Perez-Venegas et al., 2017). Investigation on pollutants especially plastic litters has received much attention because of their special characteristics such as low degradation rate, buoyancy, and long-range surface transport through ocean currents and surface winds (Cózar et al., 2014). Environmental impact assessment studies on marine litters have shown that remote islands have a higher plastic litter accumulation rate than mainland areas (Hidalgo-Ruz and Thiel, 2013), mainly because of oceanic surface current motion (Perez-Venegas et al., 2017). The plastic litters in the coastal areas of remote islands mostly came from nearby continental areas and ship movement in high seas (Veerasingam et al., 2016a, 2016b). There are many studies on the harmful effects of these plastic litters on marine biota such as fish (Carpenter et al., 1972; Bellas et al., 2016), corals (Hall et al., 2015; Hankins et al., 2018; Reichert et al., 2018) and benthic invertebrates (Naidu et al., 2018; Frydkjær et al., 2017; Renzi et al., 2018) through ingestion and bioaccumulation.

The Andaman and Nicobar Archipelago is situated between the Bay of Bengal and the Andaman Sea and comprises of 572 islands, of which 37 islands are inhabited. The islands extend from latitudes of 6° to 14° N and longitudes of 92° to 94° E. The northernmost point of the Andaman and Nicobar islands is 901 Km away from the mouth of the Hooghly River (Kolkata) and 190 km from Myanmar. The southernmost point (Indira Point – 6°45′10″ N and 93°49′36″ E) is situated at the southern tip of the Great Nicobar. The Indira Point is considered as the southernmost point of India and lies only 150 km from Sumatra in Indonesia. According to the 2011 Census of India, the population of the Union Territory of the Andaman and Nicobar Islands was 379,944 (202,330 males and 177,614 females). The islands experience tropical climate with warm temperatures wherein the average atmospheric temperature is ~23 to 31 °C and the annual rainfall in the mountainous region is ~300 mm. The Andaman and Nicobar Islands are known for their tropical rainforest canopy with endemic fauna and flora species. Among the various fauna, corals in the Andaman and Nicobar Islands are the highly productive reef ecosystem in the Indio-Pacific region. The Rani Jhansi Marine National Park (RJMNP) of the Andaman is one of the four marine national parks in India, and this area covers Outram, Henry Lawrence and John Lawrence Islands of Ritchie's Archipelago. The RJMNP consists of 148 species of Scleractinian corals belonging to 11 families, of which 37 species belong to the family Acroporidae. The percentage of live coral cover ranges from 59.53% in the Henry Lawrence Island to 63.71% in the John Lawrence Island (Raghunathan and Venkataraman, 2012), which marks the significance of this region. Hence the present study was carried out in the Andaman and Nicobar Archipelago, Andaman sea, India to study the plastic debris present in beach sediments.

To assess plastic debris contamination, beach sediment samples

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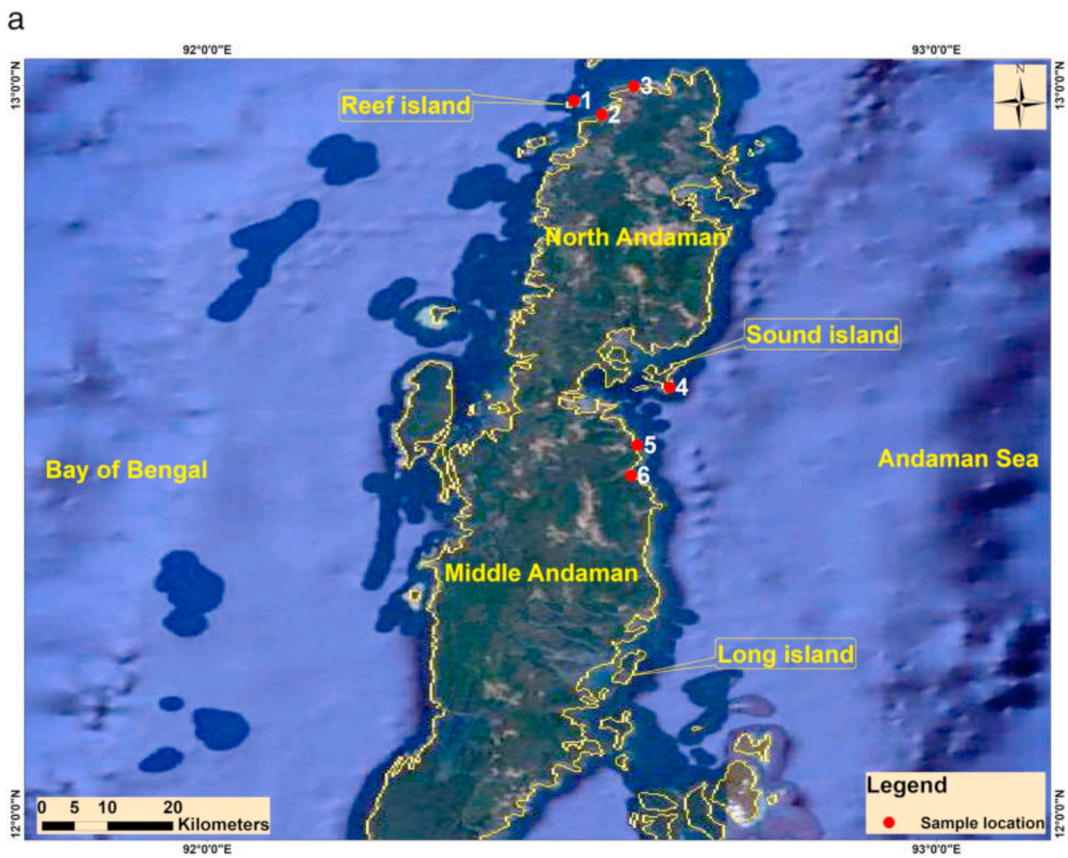
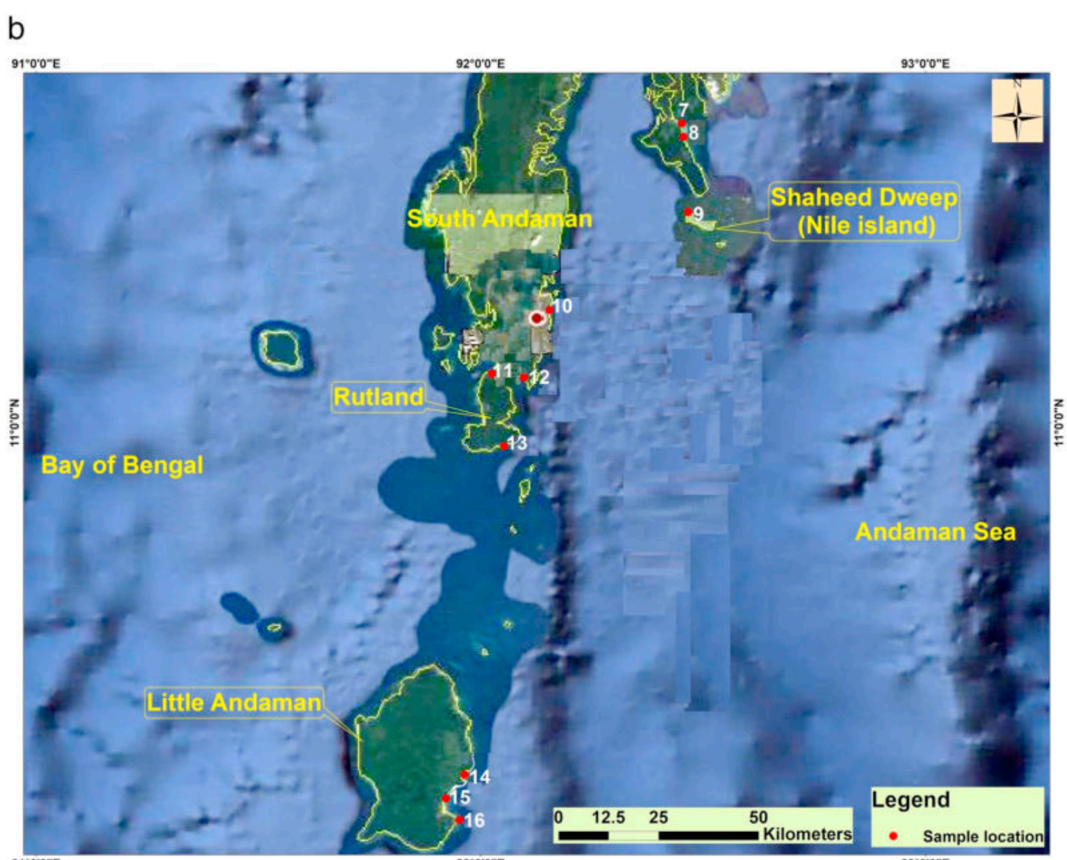


Fig. 1. a Sampling locations in the North and Middle Andaman Island. b Sampling locations in the South Andaman Island and the Rutland and Little Andaman Island. c Sampling locations in the Nicobar Island.



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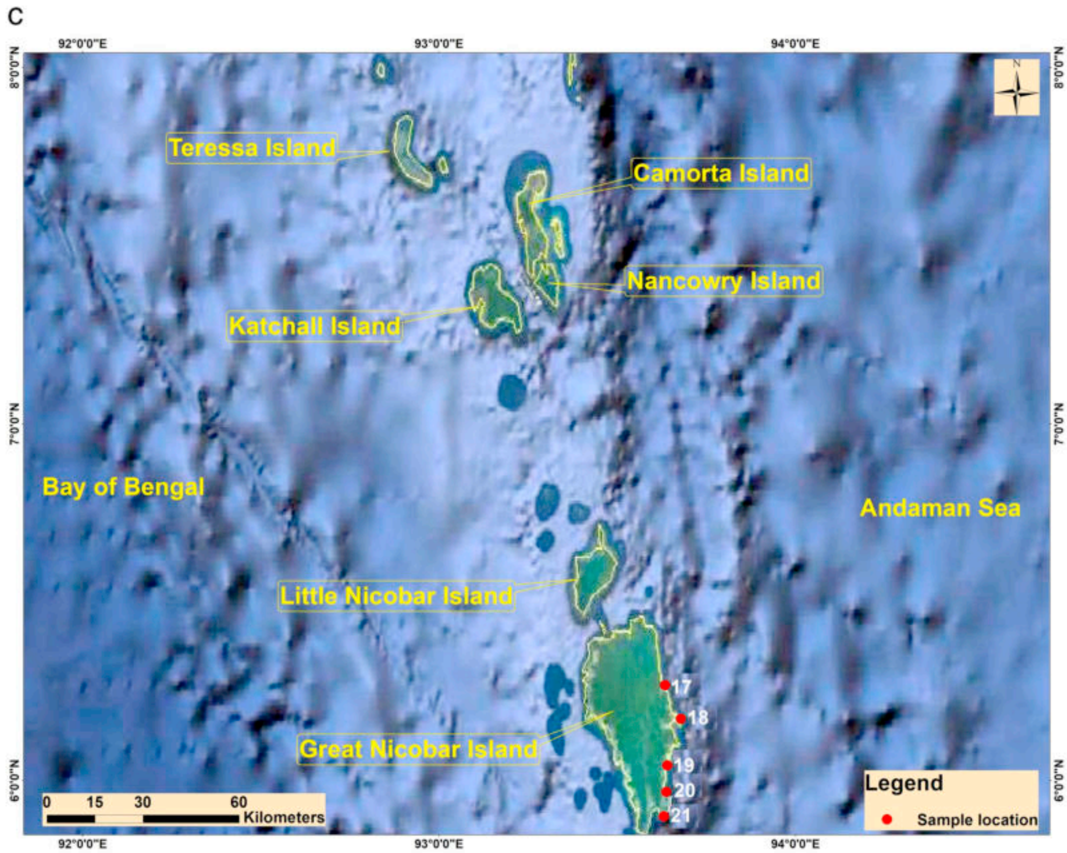

Fig. 1. (*continued*)

were collected from different locations of the Andaman and Nicobar Archipelago, India (North and Middle Andaman Island sector, South Andaman Island sector, Rutland and Little Andaman Island sector and Nicobar Island sector; Fig. 1a, b and c). To collect the sediment samples, a 1 × 1 m (length × breadth) transect was drawn and the sediments were collected up to a depth of 3 cm from the top layer. The collected samples were packed in aluminium foil sheets and brought to the laboratory for further analysis. The plastic litters in the samples were separated from beach sediments according to size: macro (> 2 mm to < 200 mm; ASTM 12) and meso (> 0.1 mm to < 2 mm; ASTM 170) using a RO-TAP sieve shaker. Microplastic particles (> 0.1 mm to < 0.45 μm) were separated from the sediments using the density separation method. The density separation method has been explained in detail in various research articles (Thompson et al., 2004; Vidyasakar et al., 2018) and the NOAA Handbook for Laboratory Methods for the analysis of microplastics in the marine environment (Masura et al., 2015).

A step by step procedure was followed to extract the microplastics from beach sediments (Vidyasakar et al., 2018; Karthik et al., 2018). First, 30 g of the sediment sample was taken and immersed in 30% H_2O_2 solution to remove the organic content; then the samples were treated with 4 N HCl solution to remove calcium carbonate. The treated beach sediment samples were mixed with 50 ml of pre-prepared zinc chloride solution (density: 1.58 g/cm^3). The mixture was filtered through a 0.45 μm nitrocellulose membrane filter paper. The filtration procedure was repeated three times for better extraction results. Finally, the filter paper was examined under an optical stereo zoom microscope for microplastics distribution.

The composition of the microplastics was confirmed by Intertek

Table 1
Name of the sampling location and total number of plastic litters in each sampling points, Andaman and Nicobar Islands.

S. no	Name of the sampling locations	Total
North and Middle Andaman sector (6 stations)		
1	Reef Island Beach	144
2	Elizabeth Bay-Gopal Nagar 2	79
3	Lambabalu-Diglipur Range	144
4	Sound Island	414
5	Karmatang Beach XI	695
6	Mayabhander-Pocket Beach	93
Total		1569
South Andaman sector (6 stations)		
7	Vijaynagar Beach (Havelock island)	55
8	Kalapathar Beach/Swaraj Dweep (Havelock island)	45
9	Laxmanpur Beach/Shaheed Dweep (Nile island)	251
10	Corbyn's cove Beach	120
11	Chidiyatapu Beach	117
12	Rifleman point (RM Point) Beach	30
Total		618
Rutland and Little Andaman Island sector (4 stations)		
13	Dhani nallah & Photo Nallah Beach	87
14	Butler Bay Beach (Little andaman)	83
15	Calapad Beach (Little andaman)	141
16	Zero point - Hut Bay, Little Andaman	429
Total		740
Nicobar Group of Islands sector (5 stations)		
17	Laxmanpur Beach - Nicobar Island	405
18	B - Quarry Beach - Nicobar Island	335
19	Laxshmi Nagar Beach - Nicobar Island	275
20	Gandhi Nagar - Nicobar Island	158
21	Sastri Nagar - Nicobar Island	105
Total		1278

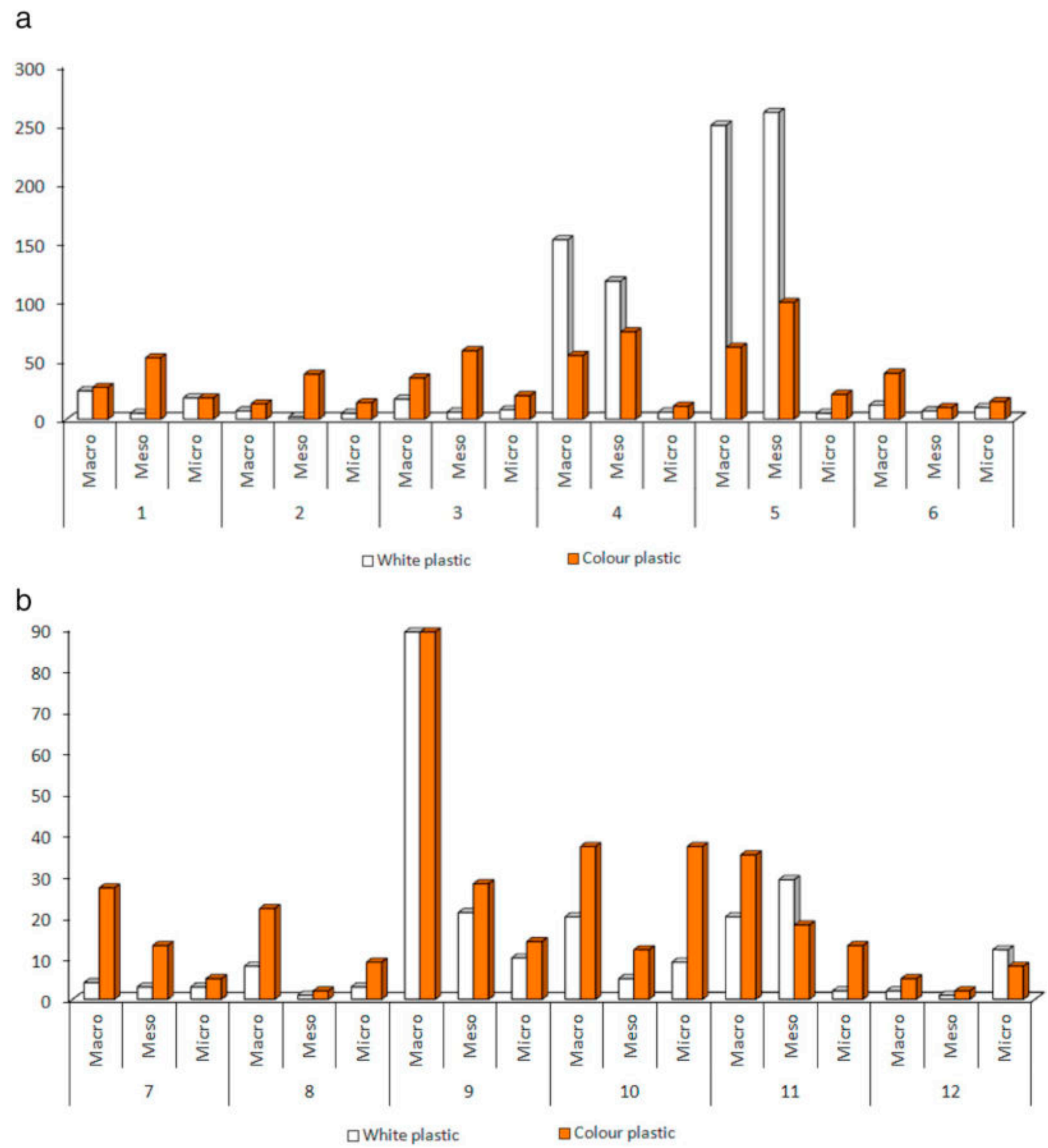

Fig. 2. a Colour classification of plastic/microplastic debris in the North and Middle Andaman Island. b Colour classification of plastic/microplastic debris in the South Andaman Island. c Colour classification of plastic/microplastic debris in the Rutland and Little Andaman Island. d Colour classification of plastic/microplastic debris in the Nicobar Island.

Fourier-transform infrared spectroscopy (FTIR) coupled with attenuated total reflectance (ATR) diamond crystal attachment to identify the separated polymer compositions. The microplastic composition frequency curve was identified using a readily available spectral library with instrument setup. The extracted plastic debris was further classified according to the colour, shape, and composition of the materials. The above classification of the debris was made under the optical stereo zoom microscope with online digital camera setup (Model – Leica DMC 4500). Two replicate studies were performed during microplastics analysis in the beach sediment samples. Simultaneously, the blank measurement was taken to eliminate external microplastics contribution during the investigation. The outcome of the study shows three microplastics at the maximum. The classified data set of the plastic debris was expressed as number of counts in each sample and represented as a pie chart. The graphical representations were prepared using Microsoft Excel software (Microsoft office 2007).

The sampling locations were set according to accessibility and local urban settlement along the coastal areas. The details of the sampling locations were as follows: 6 locations in the North and Middle Andaman Island sector, 5 locations in each of the Nicobar Island sector and the

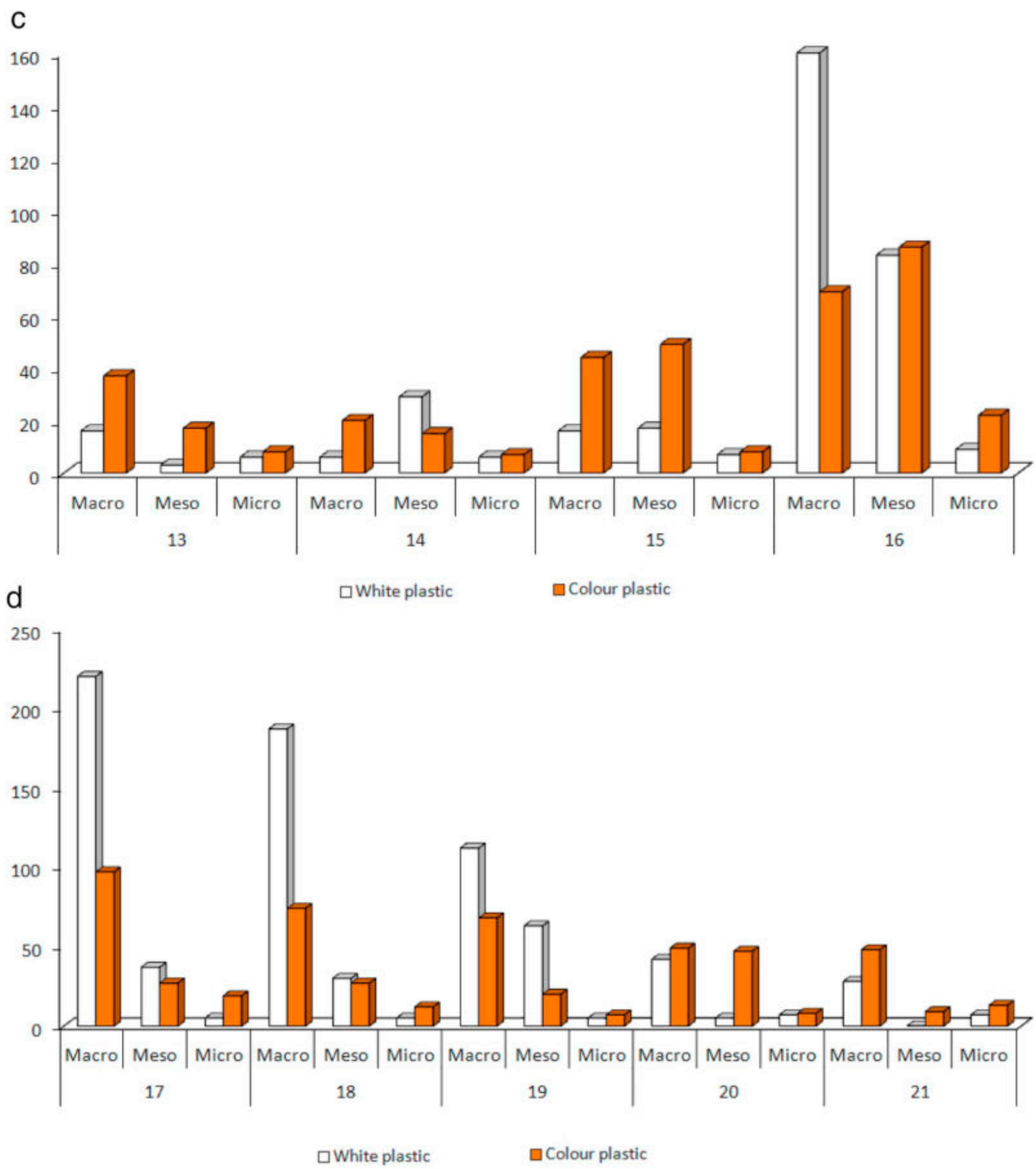

Fig. 2. (*continued*)

South Andaman Island sector, and 3 locations in Rutland and 2 locations in the Little Andaman Island (Rutland and Little Andaman Island sector). The plastic particles were classified according to colour, shape, size and composition. The total number of plastic debris at each sampling point and in each sector is shown in Table 1. The overall distribution of plastic debris was found to be in the following order: North and Middle Andaman Island sector (37.3%) > Nicobar Island sector (30.4%) > Rutland and Little Andaman Island sector (17.6%) > South Andaman Island sector (14.7%).

In the North and Middle Andaman Island sector, the distribution of plastic debris were expressed in percentage is as follows: Karmatang Beach XI (44.3%) > Sound Island (26.4%) > Reef Island (9.2%) > Lamba Balu (9.2%) > Pocket Beach – Mayabhander (5.9%) > Elizabeth Bay (5.04%). White coloured litter was found to be predominant as compared to litters of other colours and accounted for nearly 32.7% among the total litter population, particularly with more number noticed at sampling points 4 and 5 (Fig. 2a). All the studied sampling locations in the present study had significantly predominant macro and meso sized plastic litters (Fig. 3). The classification based on shape suggests that the locations had macro-sized irregular shaped materials followed by film-shaped plastic debris. The macro-sized and irregular shaped plastics were noticed at sampling sites 3, 4 and 5 in the

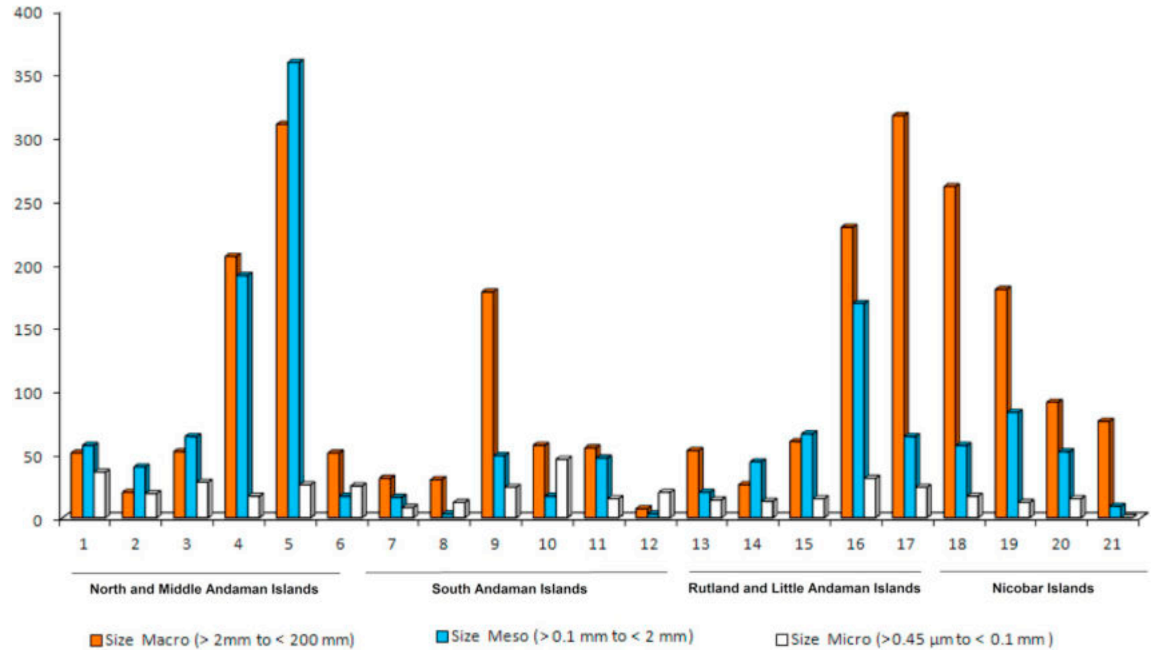

Fig. 3. Size classification of plastic/microplastic debris (macro, meso and micro sizes).

North and Middle Andaman Island sector, at sampling sites 9, 10 and 11 in the South Andaman Island sector, at sampling sites 16 in the Rutland and Little Andaman Island sector, and at sampling sites 17, 18 and 19 in the Nicobar Island sector (Fig. 4a, b, c, d). An increasing amount of polyethylene, nylon, and polypropylene materials were observed at sampling point 4 and 5. This suggests that the local geomorphology especially the curvilinear nature of the coast, might be one of the major factors that controls the distribution of these plastic litters (Fig. 5a). Nearly 7–11% of the total litter population had predominantly litters of other categories (Sound Island, and Karmatang XI). The other litter types included materials made of wood, metals, glass, rubber, etc. (121 particles). The microplastic population in this sector was slightly higher (~151 particles). Polyethylene and polypropylene were the predominant varieties found in this region (polyethylene – 550 particles; polypropylene – 669 particles). The increasing trend of the plastics in sediments is shown in the following order: polyvinyl chloride (43) > polystyrene (58) > others (121) > nylon (128) > polyethylene (550) > polypropylene (669).

In the South Andaman Island sector, the maximum count of macroplastics, especially white–coloured particles, was recorded at Laxmanpur Beach – Neil Island (251particles, sampling site 9), followed by Corbyn's Cove Beach (120 particles, sampling site 10) and Chidiya Tapu Beach (117 particles, sampling site 11) in the South Andaman Island sector (Fig. 2b). The islands have intense tourist development activities and dense local population along the coast, which might be the reason for increased amount of plastic litter. Further, the Laxmanpur had predominantly macro and meso–sized, irregular–shaped plastics, particularly polyethylene (18.3%) and polypropylene (55.3%; Figs. 4b & 5b). The maximum percentage of macroplastics (70.9%) in Laxmanpur Beach was mostly due to the nonavailability of residence time to degrade the plastic litters by daily climatic variations (Here residence time means the availability of plastic debris for degradation in the beach and marine environment). A significant amount of microplastics were found in the South Andaman Island sector (~125 particles). However, the same material composition trend as Laxmanpur was noticed in this region (polyvinyl chloride (25) > polystyrene (39) > others (65) > nylon (85) > polyethylene (136) > polypropylene (268)).

In the Rutland and Little Andaman Island sector, the maximum count of plastic litters as Karmatang XI were noticed at Zero Point – Hut Bay (sampling site 16) and Calapad beach (sampling site 15) of the Little Andaman Island. The above two sampling points had predominantly by white coloured macro–sized (23.4%) and meso–sized (56.6%) plastic litters (Fig. 2c). The vicinity of the harbor and commercial fishing activities could be the primary cause for the above observation. The other sampling stations of this sector (sampling stations 12, 13 and 14) are located far away from the urban environment. The irregular-shaped macro-and meso-sized plastics were relatively higher at sampling sites 15 and 16 (Fig. 4c). In addition, other category litters also had significantly contributed to the total beach litter population in this sector (9.9% to 13.0%; Fig. 5c). The distribution trend of microplastics in sediments was found to be slightly different from that in the South Andaman Island sector (~73 particles). The distribution trend of the plastics was in the following order: (polyvinyl chloride (4) > polystyrene (27) > nylon (75) > others (83) > polyethylene (133) > polypropylene (418)).

In the Nicobar Island sector, owing to the tremendous tourist activities and accessibility of the sampling locations, the sampling station

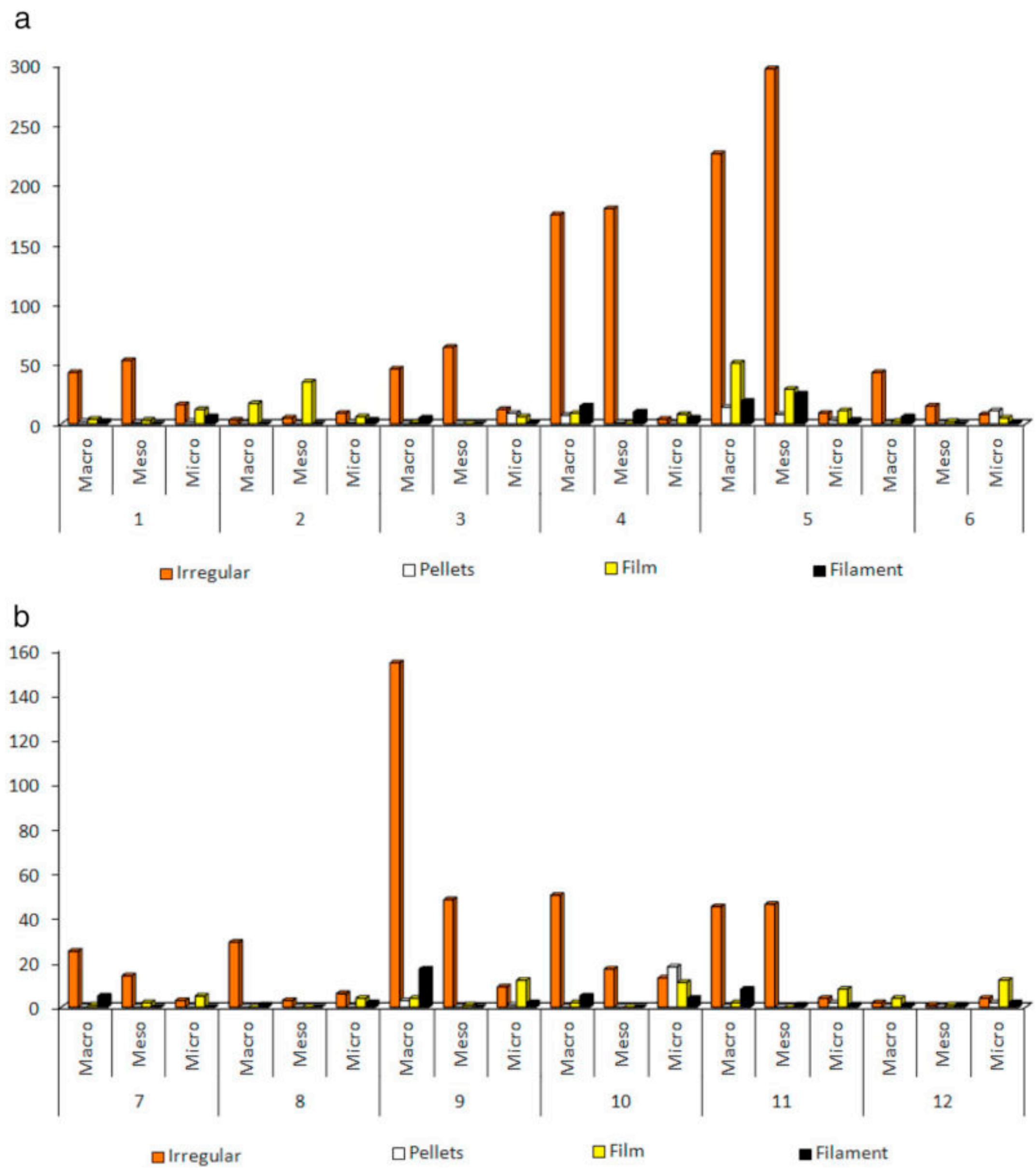

Fig. 4. a Shape classification of plastic/microplastic debris in the North and Middle Andaman Island. b Shape classification of plastic/microplastic debris in the South Andaman Island. c Shape classification of plastic/microplastic debris in the Rutland and Little Andaman Island. d Shape classification of plastic/microplastic debris in the Nicobar Island.

was fixed along the northeastern side of the Great Nicobar Island. The maximum population of plastic debris was noticed at Laxmanpur Beach (405 particles) and B-Quarry Beach (335 particles), followed by Laxmi Nagar Beach (275 particles). All the sampling sites were considerably polluted with plastic litter ($>$ 20%) except for sampling stations 20 and 21 (Fig. 2d). The percentage of the available plastic litters in the Nicobar Island sector ranged from 26.2% to 31.6%. Irregular shaped plastics were predominant in the macro-sized varieties (S. No. 17, 18 and 19). However, the maximum population of pellet-shaped plastics was noticed at sampling site 19 (Fig. 4d). The high population of polyethylene and polypropylene was noticed throughout the Nicobar Island sector (Fig. 5d). Factors such as Current/wind direction, location of the sampling point, beach profile, and local geomorphological settings play a significant role in the distribution of plastic litters along the coast. The total number of microplastics in this sector was ~88 particles. The distribution of the plastics was in the following order:

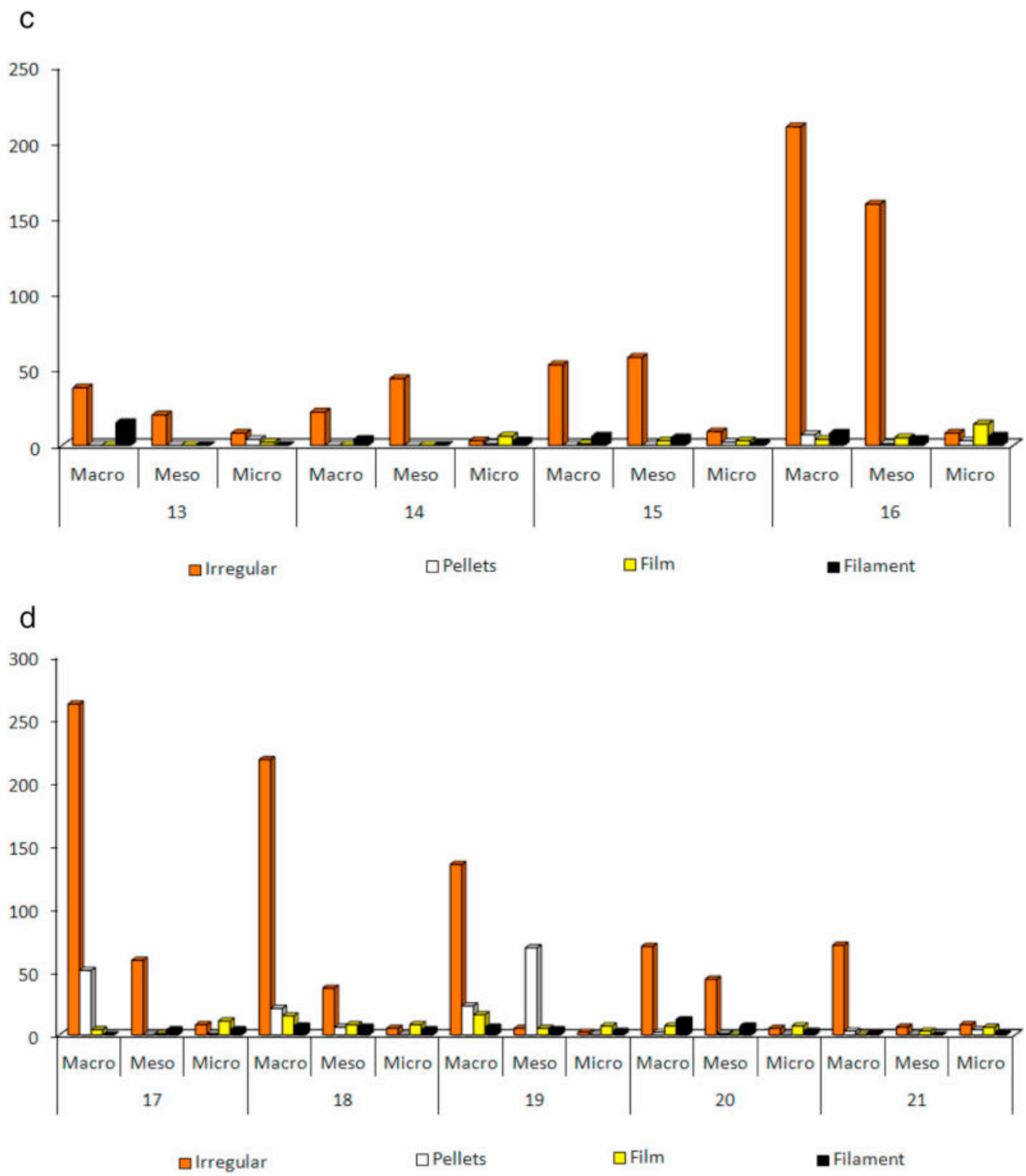

Fig. 4. (*continued*)

polyvinyl chloride (43) > polystyrene (58) > others (121) > nylon (128) > polyethylene (550) > polypropylene (669).

The overall distribution of the plastic litter in the Andaman and Nicobar Archipelago is shown in Fig. 6. The maximum plastic population was contributed by polypropylene followed by polyethylene (polypropylene: 42.64–56.49%, polyethylene: 17.97–35.05%). However, the maximum percentage of nylon (68.2%) was noticed in the Nicobar Island sector. This could be attributed to fishing activities along the coastal areas of the Andaman and Nicobar Islands and international fishing practices at the Andaman Sea. The other litter categories accounted for nearly 7% to 10% of the total plastic population in each sector. The other beach litters chiefly consisted of materials made of glass, metals, cloth wastes and organic debris. The overall plastic litter population in Andaman and Nicobar Archipelago was in the following order: North and Middle Andaman Island sector (1569 particles) > Nicobar Island sector (1278 particles) > Rutland and Little Andaman

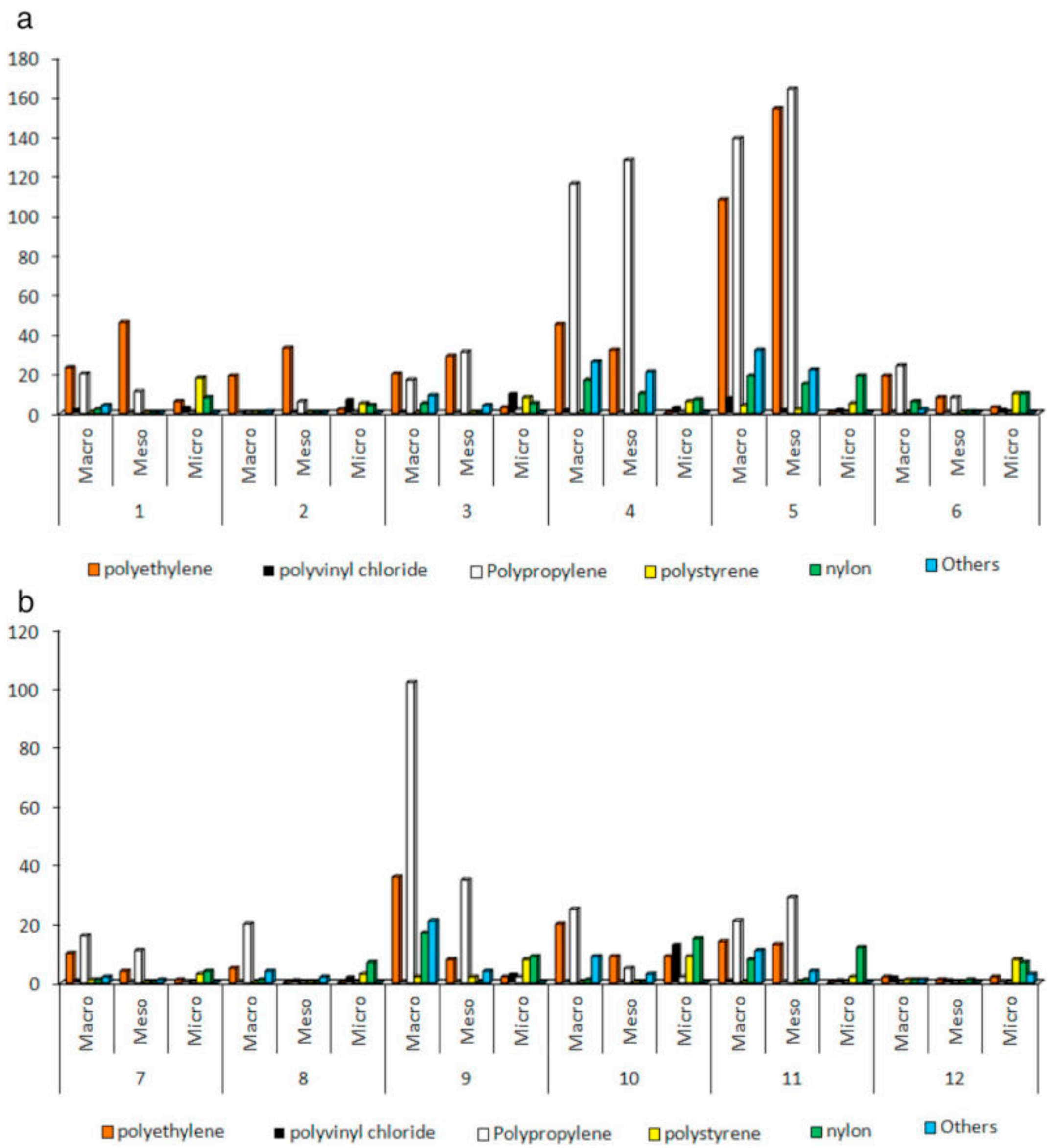

Fig. 5. a Composition classification of plastic/microplastic debris in the North and Middle Andaman Island. b Composition classification of plastic/microplastic debris in the South Andaman Island. c Composition classification of plastic/microplastic debris in the Rutland and Little Andaman Island. d Composition classification of plastic/microplastic debris in the Nicobar Island.

Island sector (740 particles) > South Andaman Island sector (618 particles). The details of the plastic debris distribution in marine sediments and the water column in various parts of the world are shown in Table 2. Most of the studies mentioned in the table have reported the microplastic population in the beach environment. However, the present report discusses the distribution of macro, meso, and microplastics in beach sediments. The comparison table suggests that the study areas and their local geological and geomorphological settings significantly affected the distribution of macro/microplastic litters, followed by population density. The significant number of plastic debris was observed at the beaches of the Andaman and Nicobar Archipelago when compared with the listed locations worldwide. The investigation of the plastic litters suggested that the significant contribution of the debris was due to increased shipping activities and improper handling of solid wastes from urban areas of the Andaman and Nicobar Archipelago, and international borders/neighbouring countries. Because of improper disposal, the plastic litters can be carried away by currents, which are circulated in the Andaman Sea and finally end up at the coastal areas of the Andaman and Nicobar Archipelago (Dharani et al., 2003).

The marine/coastal litters can attract and hold harmful hydrophobic compounds such as polychlorinated biphenyl (PCB) and dichlorodiphenyltrichloroethane (DDT) and enrich them above the background level (Allen et al., 2018; Tang et al., 2018). Thus, the ingested floating plastic litter poses potential health risk hazards to

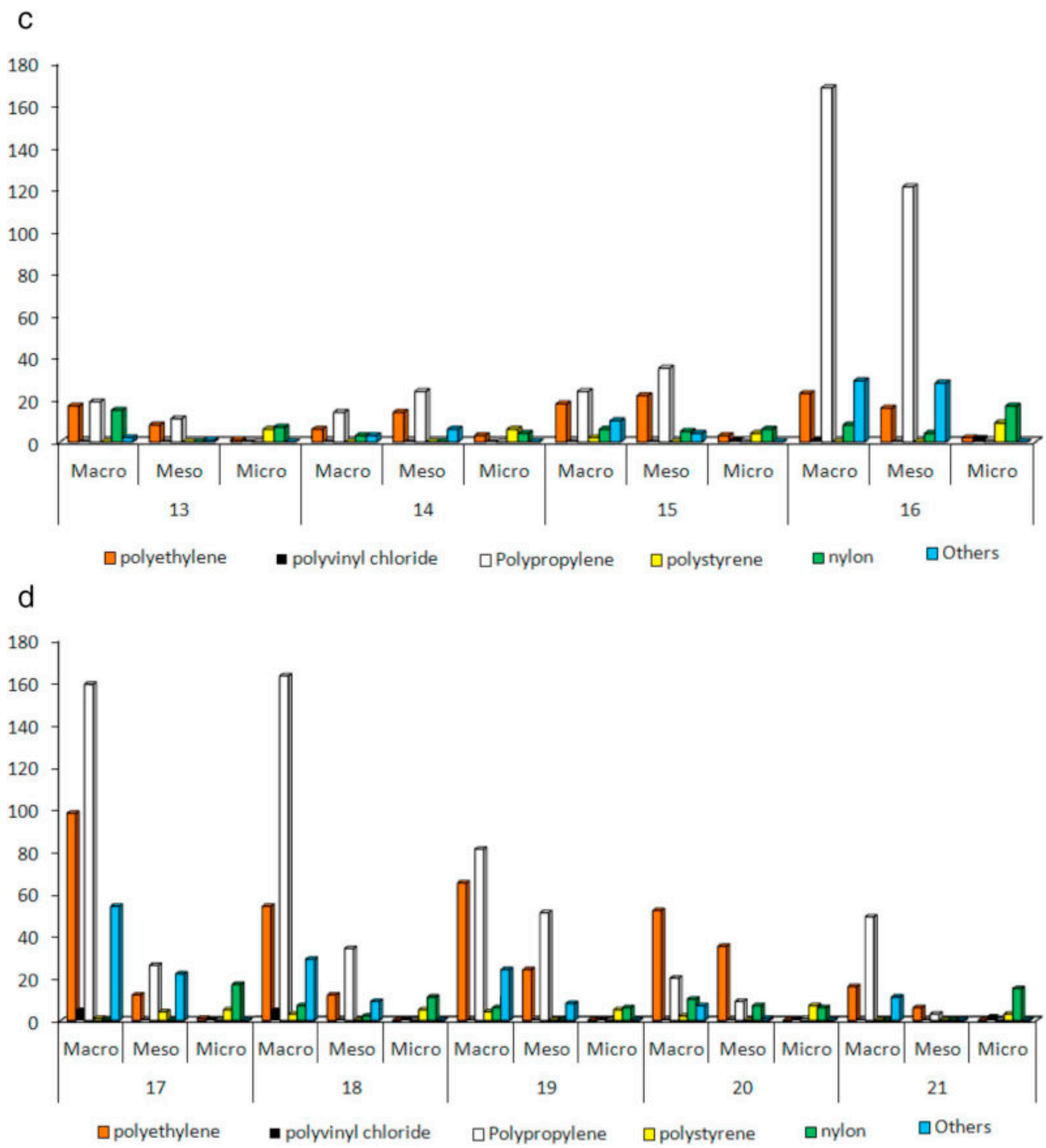

Fig. 5. (*continued*)

marine organisms. Government/nongovernmental organizations must take measures to conduct periodic coastal and marine cleanup campaign to reduce coastal/marine litter problems. Creating awareness to the general and coastal communities, proper solid waste management, and recycling of plastic litter will provide effective solutions to prevent coastal litters.

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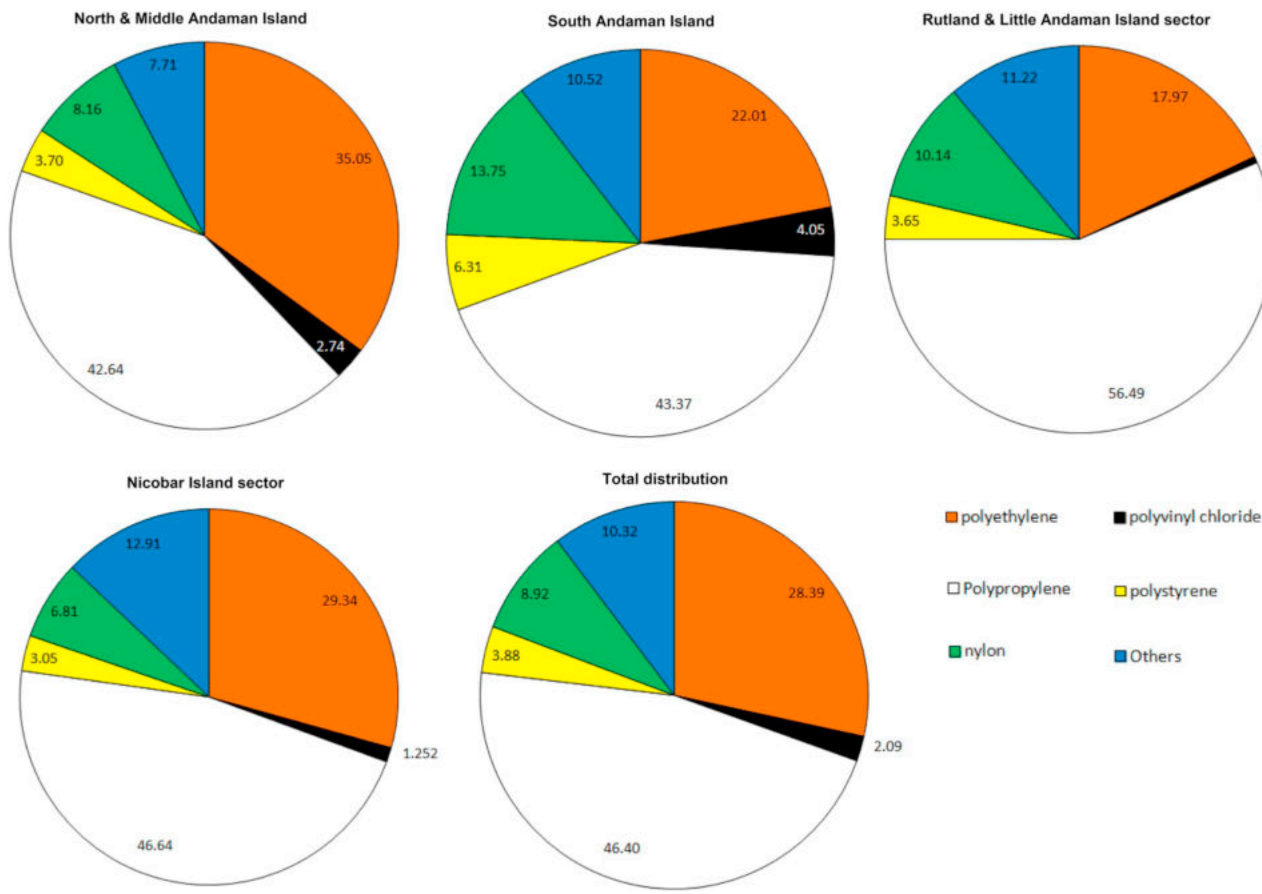

Fig. 6. Classification by percentage and overall composition of plastics in the Andaman and Nicobar Archipelago.

Table 2
Distribution of plastic litters from marine sediments, water column from various parts of the world.

S. no	Sampling location		No of items	References
1	Canary Island beaches, Africa		< 1 ≥ 100 g/L	Baztan et al., 2014
2	East Frisian Islands, Germany		1–14/10 g/DW	Liebezeit and Dubaish, 2012
3	Bays and beaches of Huatulco, Mexico	Apr-13	0–48/10 g DW	Retama et al., 2016
		Dec-14	2–69/10 g DW	
4	Hawaiian Archipelago beaches		541–18,559 Items/260 L	McDermid and McMullen, 2004
5	Alang-Sosiya ship-breaking yard, India		10	Reddy et al., 2006
6	Mumbai beaches, India		3	Jayasiri et al., 2013
7	Chennai coast, India	Mar-15	24–43	Veerasingam et al., 2016a
		Nov-2015	66–148	
8	Rameswaram Island coast		403 pieces	Vidyasakar et al., 2018
9	Canadian Lake Ontario sediments		> 500 Particles/kg DW	Ballent et al., 2016
10	Mangrove wetlands,Qinzhou Bay, China		(15–12,852 ítems kg^{-1})	Li et al., 2018
11	Beach sediments, Ontario shoreline of Lake Erie		1178 Pieces	Dean et al., 2018
12	Marine and beach sediments, Southern Baltic Sea		25 particles kg^{-1} DW to 25 particles kg^{-1} of DW	Graca et al., 2017
13	Beach sediments, German Baltic coast		0–7 Particles/kg DW	Stolte et al., 2015
14	Beach sediments, Isle of Rügen (Baltic Sea)		2862.56 Particles per m^2 or 88.10 particles/kg	Hengstmann et al., 2018
15	European beach sediment		72 ± 24 to 1512 ± 187 particles/kg of DW	Lots et al., 2017
16	Sandy beaches of the Baja California Peninsula, Mexico		135 ± 92 particles kg^{-1}	de Jesus Piñon-Colin et al., 2018
17	Southwest coast of Kerala		0–150 particles/m^2 Beach sediments 0–4 particles/m^3 Coastal waters	Robin et al., 2019
18	Beach sediments of Andnman and Nicobar archipelago	North &b Middle Andaman Island sector	Macro – 690; Meso – 728; Micro – 151 Particles	Present study
		South Andaman Island sector	Macro – 358; Meso – 135; Micro – 125 Particles	
		Rutland & Little Andaman Island sector	Macro – 368; Meso – 299; Micro – 73 Particles	
		Nicobar Island sector	Macro – 925; Meso – 265; Micro – 88 Particles	

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