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Development of Regional Action Plan On Marine Litter

MARINE LITTER IN THE SOUTH ASIAN SEAS (SAS) REGION

Country Report - INDIA

United Nations Environment Programme (UNEP)
South Asia Cooperative Environment Programme (SACEP)
Ministry of Earth Sciences (MoES), Government of India

MARINE LITTER IN THE SOUTH ASIAN SEAS (SAS) REGION

DEVELOPMENT OF REGIONAL ACTION PLAN ON MARINE LITTER

INDIA – COUNTRY REPORT

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सत्यमेव जयते
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FOREWORD

The South Asian Seas (SAS) region consist of two distinct geographical groups. India, Pakistan and Bangladesh are situated on the Asian mainland, whereas Sri Lanka and Maldives are Island nations. The SAS regions are biologically rich marine ecosystems, such as the Gulf of Mannar, Atolls of Maldives and Mangroves of Sundarbans. The presence of perennial rivers such as the Brahmaputra, Ganges, Godavari, Indus, Kelani, Magna, etc. have contributed to large networks of backwaters, estuaries, salt marshes and mangroves.

The region also supports habitats for endangered marine turtles, viz., the Green and Olive Ridley turtles, some of the largest coastal lagoons of the world i.e., Chilka Lake in India and Puttalam lagoon in Sri Lanka. It has one of the world's finest coral ecosystems, with atolls constituting the entire country of Maldives; Lakshadweep and Nicobar group of islands of India and a few regions of Sri Lanka have fringing reefs.

Studies indicate that a large amount of land based debris and pollutants including plastics is entering into the Indian Ocean. However, the threat and impacts of marine litter (especially microplastics) have long been ignored. Surveys have showed that nearly 80 percent of marine debris originates from land-based activities and around 70 per cent of the litter entering to the oceans lands on the seabed, 15 per cent on beaches and 15 per cent remains floating on the surface.

Litter that are accumulating in the marine environment is causing a global environmental nuisance with numerous adverse effects. Studies on litter composition and sources along the coastal waters of India are scanty and fragmentary. Therefore, a detailed study focusing marine litter is highly essential in the present context and will develop a data base for marine litter management in India and in the South Asian Seas (SAS) region through the preparation of a Regional Action Plan on Marine Litter. This report is useful for the implementation of Sustainable Development Goal 14 (SDG 14): 'Conserve and sustainably use the oceans, seas and marine resources for sustainable development'.

I am happy to say that this report, though a preliminary and first of its kind, can prompt for further actions against marine litter in all coastal regions in and around India. An attempt has been made to highlight both impacts of marine litter and measures that can prevent the input of plastics into the ocean, and reduce the amount of litter that already is in the marine environment based on the available literature for the region. A set of recommendations for decision-makers in governments, agencies, and commercial enterprises are presented in the report. I hope this report will act as a baseline survey for India and will provide an impetus for undertaking detailed research and also preparation of a regional plan to address issues in a holistic way for the SAS region.

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EXECUTIVE SUMMARY

In the last few decades, there have been numerous anthropogenic driven changes to our planet and one of the most evident change is the ubiquity and abundance of litter in the marine environment. It is widely recognized that pressures and demands on marine resources are often excessive, and that action must be taken in order to minimize negative impacts on the marine environment. In order to substantially reduce marine litter and microplastics, it is essential to develop national and regional policy/action plan and evolve appropriate programmes to tackle the menace of marine litter. In the entire SAS region, data and/or information about the marine litter (especially microplastics) is limited.

It is towards this end, the South Asia Co-operative Environment Programme (SACEP) has attempted to develop a data base for marine litter and microplastics management in the South Asia Seas (SAS) region and has initiated the preparation of a Regional Action Plan on Marine Litter. The Ministry of Earth Sciences (MoES), Government of India (GoI) through its National Centre for Coastal Research (NCCR) Chennai, has been entrusted to prepare a Country Report on Marine Litter in India.

In India, according to Central Pollution Control Board (CPCB), ~15,343 tonnes/day of plastic waste is being generated from 60 major Indian cities. The four major metropolitan cities contribute the maximum with Delhi generating 689.5 tonnes/day, Chennai (429.4 tonnes/day), Kolkata (425.7 tonnes) and Mumbai (408.3 tonnes) of the total collected plastic waste only 60% (9205 tonnes per day) is recycled while the fate of the remaining 40% is not accounted for. Polyethylene (PE) and Polypropylene (PP) are the abundant polymer types found on the marine/beach litter around the coast of India. In addition to macro/microplastic debris, tar ball deposition along the west coast of India during the southwest monsoon is another environmental issue.

In a bid to control litter and build a clean and sustainable environment, Government of India, has initiated several programmes such as “Swachh Bharat Abhiyan”, National Mission for Clean Ganga and Smart Cities Mission”. In order to educate the public and create more awareness on the need for a clean and healthy coast, the Ministry of Earth Sciences in association with SACEP, UNEP, SAS, Indian Coast Guard conducted the International Coastal Cleanup (ICC) day 2017 on 16th September 2017 in various parts of India.

It is clear, that no major scientific study has been undertaken on marine litter and there is very little information/data available on floating/submerged marine litter/debris in the entire SAS region including India.

This report has been compiled based on the primary and secondary data available and could serve as a baseline information on the status of marine litter in India. The report would aid in preparation of the regional plan for combating marine litter in the SAS region and will also provide an impetus for undertaking detailed research in this area. As part of the development of regional action plan on marine litter, the existing legislation, regulations and enforcement mechanisms/practices in the various SAS countries) would have to be evaluated and strengthened by a new legislation/regulation to combat the menace of marine litter.

1. INTRODUCTION AND BACKGROUND

Marine litter (ML) includes any form of anthropogenic manufactured or processed materials discarded, disposed of, or abandoned in the marine environment, either deliberately or unintentionally, and may be transported to the ocean by rivers, drainage, sewage systems or by wind. ML is also defined as waste created by humans that has been discharged into coastal or marine environments, resulting from activities on land or at sea (UNEP, 2011). ML comprises of various material types, and can be classified into several distinct categories (Galgani et al., 2010).

(1) **Plastics**, covering a wide range of synthetic polymeric materials, including fishing nets, ropes, buoys and other fisheries- related equipment; consumer goods, such as plastic bags, plastic packaging, plastic toys; tampon applicators; nappies; smoking-related items, such as cigarette butts, lighters and cigar tips; microplastic particles.
(2) **Metal**, including drink cans, aerosol cans, foil wrappers and disposable barbeques.
(3) **Glass**, including bottles, bulbs
(4) **Processed timber**, including pallets, crates and particle boards.
(5) **Paper and cardboard**, including cartons, cups and bags
(6) **Rubber**, including tyres, balloons and gloves.
(7) **Clothing and textiles**, including shoes, furnishings and towels
(8) **Tar balls,** including oil residues

The majority of ML consists of plastics. Plastics are generally divided into macro-plastics and the smaller microplastics; the plastic particles <5 mm in diameter including nanoplastics (UNEP, 2016).Common smaller macroplastic parts (<2.5 cm) can originate from direct and indirect sources such as lost bottle caps or plastic fragments; common macroplastics, smaller than 1 m, originating from rivers or maritime sources such as plastic bags, food and other packaging, fishing floats, buoys, balloons and macroplastics larger than 1 m from fishing activities or catastrophic events such as abandoned fishing nets and traps, rope, boat hulls and plastic films from agriculture. There are two types of microplastics; primary microplastics that have been made intentionally (such as pellets or microbeads) and secondary microplastics that are fragmented parts of larger objects (GESAMP, 2016).

The global production of plastic has grown from 1.5 million tons in 1950 to 322 million tons in 2015. In these few decades, plastics have replaced materials such as wood, metal, and glass, and there is no indication that this trend will be reversed in the near future. The presence of litter lying on beaches, hanging on reefs, or floating around islands are unwelcome expressions of the omnipresence of plastic in contemporary society. Jambeck et al. (2015) estimated that between 4.8 and 12.7 million tons of land-based plastic waste ends up in the ocean every year. Moreover, global plastic production increases each year, it already exceeded 300 million tons in 2014 (Plastics Europe, 2015). If the current trend of a 5% production increase per year continues, an additional 33 billion tons of plastic will have piled up around the globe by 2050 (Rochman et al., 2013).Plastics not only negatively affect aquatic ecosystems, but also societies and their economics. Economic activities such as shipping, fishing, aquaculture, tourism and recreation are directly affected by plastic pollution and the total negative impact on oceans has been estimated at least $8 bn per year (UNEP, 2014). Moreover, there is an increasing concern about the risks and possible adverse effects of microplastics to organisms and human health (Thompson et al., 2009).

At sea, plastic materials degrade slowly and do not readily mineralize; instead, they break down into ever-smaller fragments over time, which persist in the marine environment. Buoyant plastic litter is globally distributed by ocean currents and is found washed ashore on beach lines around the globe where it negatively impacts ecological and human systems both in the open water and on the coast. Plastics end up in the marine environment through leaks from the global value chains that run from the oil industry through various other industries to local retailers and consumers. The plastic are lost from production to disposal through transport, production, use, waste collection, and waste treatment. In the environment, the very same qualities of lightness and resistance that make them attractive to producers and consumers turn them into a nuisance for other species.

There are thousands of different types of plastics, but a more limited range shows up in ML. Many research studies have identified polyethylene (PE), polypropylene (PP), and polyterephthalate (PET) together with various types of foamed plastics [expanded polystyrene (PS), synthetic rubber, etc.). Moreover, nylon, which is used for ropes and fishing nets, is commonly found. These four materials are among the six material groups – also including polyurethane (PUR) and polyvinylchloride (PVC) – that make up 80% of all plastics production. The plastics that show up in beached ML are typically those used in litter-prone applications (e.g. packaging) and hard to contain applications (e.g. nurdles and fishing gear) and are buoyant (e.g. PE and PP). Heavier plastic items (e.g. PVC) tend to sediment near the location where they are lost.

The material properties, densities, and purposes of plastic items affect their distribution and fate in the environment. Materials with low density (e.g. PE and PP) will typically float and are thus more common on beaches and in surface waters, whereas higher density materials (PVC, PET, PUR, and PS) are more often found in sediment and on the ocean floor. However, high-density polymers can also end up on beaches due to the material properties of the plastic item, e.g. the expanded form of PS used for buoys, insulation, and Styrofoam cups. Conversely, low density materials can sink to the bottom as a consequence of biofouling, which is the growth of algae, barnacles, and microorganisms on the surface, and from degradation. Thus the properties of plastic litter might change once it is in the environment.

Not only is plastic litter made up of different polymeric materials, it also comes in different sizes, from bigger macroscopic items down to microplastic and nanoparticles. This has implications for ecological impact of the litter. Beach litter varies in composition depending on location, proximity to local sources, and environmental conditions and ranges from recognizable items to smaller pieces. Common items include packaging foils, plastic bags, food containers, drinking bottles, oil canisters, Styrofoam, pieces of ropes and nets, gloves, shoes, fish crates and floats, and sanitary items. Smaller objects commonly include bottle caps, lighters, cigarette butts, sewage plant bioreactor pieces, and shotgun cartridges.

Sources and pathways of ML are diverse and exact quantities and routes are not fully known. There is, however, a lot of research that aims to determine the exact quantities and types of plastic litter and pathways in the environment. Most of the plastic in our oceans originates from land-based sources. A study by Jambeck et al. (2015) revealed that developing economics are the most polluting. The study also showed that 83% of the 4.8 – 12.7 million tons of land-based plastic waste that ends up in the ocean from the 192 coastal countries originates from 20 countries (China, Indonesia, the Philippines, Vietnam, Sri Lanka, Thailand, Egypt, Malaysia, Nigeria, Bangladesh, South Africa, India, Algeria, Turkey, Pakistan, Brazil, Burma, Morocco, North Korea and United States). Total annual waste generation was mainly determined by population size, hence the large populations of the leading countries on the list. The amount of plastic waste eventually ending up in the ocean was mainly determined by the percentage of mismanaged waste. A study by Lebreton et al. (2017) estimated that between 1.15 and 2.41 million tons of plastic waste flows from rivers into the ocean annually, likewise the main drivers were population density, mismanaged plastic waste and production per country. The top 20 ~~of~~ polluting rivers were mostly located in Asia, and accounted for 67% of the global total (Yangtze, Xi, Huangpu, Dong, Zhuijang, Hanjiang in China; Brantas, Solo, Serayu and Progo in Indonesia; Pasig in the Philippines; Irrawaddy in Myanmar; Imo in Nigeria; Magdalena in Columbia; Tamsai in Taiwan; Kwa Ibio in Nigeria; the Ganges in India/Bangladesh; Cross in Nigeria/Cameroon; Amazon in Brazil/Peru/Columbia and Ecuador and the Mekong in Thailand/Cambodia/Laos/China/Myanmar and Vietnam).

Currently, there are several global efforts aiming at action for reducing and preventing ML and for mitigating its impacts. These include worldwide initiatives, for example, by the Global Partnership on Marine Litter (GPML), the Honolulu Strategy (UNEP, 2011) and the G7 countries (G7, 2015). GPML is a voluntary multi-stakeholder coordination mechanism which brings together policymakers, civil society actors, the scientific community and the private sector to discuss solutions and catalyze actions. The Honolulu Strategy is a planning framework for the prevention and management of ML and an effort to reduce the ecological, human health, and economic impacts of ML globally. It has a set of three specific goals to reduce ML and linked to each goal is a cohesive set of strategies:

Goal A: reduced amount and impact of land-based litter and solid waste introduced into the marine environment;
Goal B: reduced amount and impact of sea-based sources of marine debris including solid waste, lost cargo, abandoned, lost or discarded fishing gears (ALDFG), and abandoned vessels introduced into the sea; and
Goal C: reduced amount and impact of accumulated marine debris on shorelines, in benthic habitats, and in pelagic waters.

At the 2015 G7 summit the protection of the Marine Environment was high on the agenda too and it was acknowledged that ML, in particular plastic litter, poses a global threat. More and more countries are taking action against ML during the 2016 United Nations Environment Assembly (UNEA-2) countries unanimously adopted a stand-alone resolution on ML. The resolution acknowledged marine plastic and microplastic as a rapidly increasing, serious problem of global concern that urgently needs a global response. The resolution signals countries continued willingness to put marine plastic pollution high on the environmental policy agenda. In order to keep it also high on national agendas, pollution will be the focus of the 2017 UN Environment Assembly in December.

The solution to ML is likely to be found in a transition towards more sustainable ways of production and consumption that are also promoted via the Sustainable Development Goals (SDGs). The UN sustainable development agenda represents a plan of action involving 17 SDGs and includes targets to prevent and significantly reduce marine pollution of all kinds, including ML. Such a sustainability transition is a context-dependent, non-linear, evolutionary process that will include successes as well as failures (Bowen et al., 2017). It requires collective actions amongst a large diversity of actors across sectors and scales, and dealing with divergent perspectives and interests (Assche et al., 2017).

Four of the SDGs have targets relevant to marine plastic pollution (Table 1). These targets deal with untreated wastewater, waste management in sustainable cities, management of waste throughout their life cycle – with focus on prevention, reduction, recycling and reuse – and sustainable management of oceans.

Table 1: Sustainable Development Goals related to Marine Litter (ML) (based on UN-SDG, 2017)

S. No	Sustainable Development Goal (SDG)	SDG target related to ML
1	SDG 6 Clean water and sanitation • Ensure availability and sustainable management of water and sanitation for all.	Target 6.3: focus on untreated wastewater By 2030, improve water quality by reducing pollution, eliminating dumping and minimizing release of hazardous chemicals and materials, having the proportion of untreated wastewater and substantially increasing recycling and safe reuse globally.
2	SDG 11 Sustainable cities and communities • Make cities and human settlements inclusive, safe, resilient and sustainable.	Target 11.6: focus on municipal and other waste management. By 2030, reduce the adverse per capita environmental impact of cities, by paying special attention to air quality and municipal and other waste management.
3	SDG 12 Responsible consumption and	Target 12.4: focus on environmentally sound management of chemicals and all wastes throughout

	production • Ensure sustainable consumption and production patterns.	their life cycle. By 2020, achieve the environmentally sound management of chemicals and all wastes throughout their life cycle, in accordance with agreed international frameworks, and significantly reduce their release to air, water and soil in order to minimize their adverse impacts on human health and the environment. Target 12.5: focus on waste generation reduction through prevention, reduction, recycling and reuse. By 2030, substantially reduce waste generation through prevention, reduction, recycling and reuse.
4	SDG 14 Life below water Conserve and sustainably use the oceans, seas and marine resources for sustainable development	Target 14.1: focus on waste generation reduction By 2025, prevent and significantly reduce marine pollution of all kinds, in particular from land-based activities, including marine debris and nutrient pollution. Target 14.2: focus on sustainable management By 2020, sustainably manage and protect marine and coastal ecosystems to avoid significant adverse impacts, by strengthening their resilience, and take action for their restoration in order to achieve healthy and productive oceans. 14.c conservation and sustainable use of oceans Enhance the conservation and sustainable use of oceans and their resources by implementing international law as reflected in UNCLOS, which provides the legal framework for the conservation and sustainable use of oceans and their resources as recalled in paragraph 158 of the Future We Want.

At the June 2017 United Nations Conference to Support the Implementation of Sustainable Development Goal 14 of the 2030 Agenda affirmed a strong commitment to conserve and use our oceans, seas and marine resources for sustainable development. To increase global action leadership and commitment by government at all levels is needed.

2. MARINE LITTER STATUS AT NATIONAL LEVEL

2.1 Origin, typology, pathways and trends:

In this report the term 'source' is adopted to indicate the economic sector or human activity from which litter originates but specify further the means of release to indicate the mechanism or the way in which a given item leaves the intended cycle and/or enters the natural or urban environment and becomes a problem. The 'geographic origin' can thus be defined by the geographic location of the source and where the release took place. This origin can be, and often is, distant from the sea or the site where ML item is recorded. Being able to distinguish between the wastes that is generated locally, regionally and globally, is important when deciding on appropriate measures to prevent ML in a certain area.

Litter pollution in a given area can be of local origin – directly discarded on the beach or in the sea in that area – or can be transported from inland via rivers and runoff or transported from distant regions via ocean currents and the prevailing wind. Sometimes river or ocean currents are described as sources. However, these are actually 'transport mechanisms', which move litter into and within the marine environment from various land- and sea-based sources. The 'pathways' can be consider the physical and/or technical means by which litter enters the marine environment (Veiga et al., 2016). In Table 2, the possible sources, pathway and transport mechanisms of marine litter are listed.

Table 2.The possible sources, means of release, geographic origin, pathways and transport mechanism for a few MLs found in Indian Ocean (Data source: Bouwman et al., 2016; Duhec et al., 2015; Suneel et al., 2016).

Types of litter	Source	Means of release	Geographic origin	Pathway	Transport mechanism
Flip-flops (sandals)	Consumers/ General public	Discard after use	Local (beach), regional (nearby towns) and international (nearby countries)	Direct entry (if at beach) and through river (if distant)	Rivers, wind, ocean currents and tides
Glass bottles	Consumers/General public/ tourists	Discard after use	Local (beach), regional (nearby towns) and international	Direct entry (if at beach) and through river (if distant)	Rivers, wind, ocean currents

			(nearby countries)		and tides
Plastic beverage bottles	Consumers/General public/ tourists	Discard after use	Local (beach), regional (nearby towns) and international (nearby countries)	Direct entry (if at beach) and through river (if distant)	Rivers, wind, ocean currents and tides
Fishing items	Fisheries	Discard or unintentional loss over board during net repair work at sea	E.g., Local fisheries, regional fisheries or distant fisheries	Direct entry – nets get washed or thrown overboard	Winds (drift), currents and tides
	Fisheries	Loss of nets and pieces of net during fishing (snagging)	E.g., Local fisheries, regional fisheries or distant fisheries	Direct entry – nets get snagged on wrecks, rocks etc. ripped off pieces of net remain attached to objects	Winds (drift), currents and tides
	Fisheries and/ or harbours	Discard or unintentional loss during net repair work on land or/and runoff from harbours	E.g., Local fishing harbours	Direct entry – nets washed, blown or thrown (swept) into harbor basins and washed out to sea	Winds (drift), currents and tides
Tar balls	Offshore oilfields and tanker wash	Tanker accidents and/or Unintentional leakage in offshore oilfields and natural seepage.	Local (beach), regional (nearby towns) and international (nearby countries)	Direct entry (if at sea) and through river (if at land)	Winds (drift), currents and tides

2.2 Classification of marine litter

ML originates from a wide and diverse range of sources. The majority of ML (nearly 80%) entering the seas and oceans is considered to originate from land-based sources, including sewage treatment, combined sewer overflows, people using the coast for recreation or shore fishing, shore-based solid waste disposal, inappropriate or illegal dumping of domestic and industrial rubbish, poorly managed waste dumps, street litter which is washed, blown or discharged into nearby waterways by rain, snowmelt, and wind, etc. the remaining can be attributed to maritime transport, industrial exploration and offshore oil platforms, fishing and aquaculture and loss and purposeful disposal (e.g. ballast weights made of steel, lead or cement) of scientific equipment(UNEP, 2009).

The recent study by Duhec et al. (2015) found that based on labeling of the collected MLs in Indian Ocean, they identified the country of origin from the text and language of manufacturer marks. The most frequently collected plastic water bottles were labeled *Nongfu Spring* (18 bottles and 2 caps) manufactured in China, followed by *Danone Aqua* from Indonesia. Also abundant (5 bottles and 9 caps) were labeled Mizone, a sport drink manufactured and broadly consumed in Indonesia. Other beverage bottles included: Minute Maid 4 bottles and 9 caps), C'est Bon, Wahaha and Bonaqua (each encountered only once) were presumably manufactured from China. Bottles and caps of Coca Cola, Sprite, Orangina, Pepsi, Fanta, were easily recognizable but the country of manufacture was not discernible.

Glass bottles were predominantly for beverage drinks with 4% being energy drinks. The label Kratingdaeng, manufactured in Thailand and Indonesia, was the most frequently encountered (N=70), followed by Djojonegro (N=9) manufactured in Indonesia, Osotspa (N=4) manufactured in Thailand, Red bull Supreme (N=2) manufactured in Philipines, Zoda manufactured in Thailand (N=1), and Paolyta (N=1), and Courage (N=1) both were manufactured in USA. Overall, 94% of the energy drink bottles washed ashore were manufactured in Asia.Identifiable fishing buoys and floats included those manufactured in Taiwan (N=3) and Norway (N=1). Overall, more than 75% of labeled items originated in Southeast Asia (mainly Indonesia and Thailand), 13% from East Asia (mainly China), 4% from Indian Ocean Islands and 7% from other countries (Spain, Brazil, Chile, South Africa, AEU, UK, USA and Norway).

2.3 Quantification (if possible type of litter)

Quantification of marine litter including plastics in the water column, sediment and biota has been documented in the Indian beaches, estuaries, coastal waters and Open Ocean. However, comparisons between studies or even systematic status and trend analyses are challenging because of differences in the collection and measurement methodology used.

West coast of India:

(i) Alang-Sosiya ship-breaking yard, Gujarat

Alang-Sosiya ship-breaking yard is the world's largest ship-breaking zone, with an annual turnover of US$ 1.3 billion and is on the western coast of Gulf of Khambhat. The site experiences a high tidal range (~13 m), and it is characterized by a relatively wide continental shelf, mud-free coast, gentle sloping and firm seabed, which makes it ideal for ship-breaking activities. On an average, 180 ships from various countries are dismantled every year in this yard.

The accumulation of small plastic debris in the intertidal sediments at Alang-Sosiya ship breaking yard, India was assessed by Reddy et al. (2006). The four polymers (polyurethane, nylon, polystyrene, polyester, and glass wool) identified in extracts from sediments are normally used in the construction of ships and in the making of associated components such as insulating materials, fabrics, packaging, etc (Figure1& 2). Overall, there were on average 81 mg of small plastics fragments per kg of sediment.

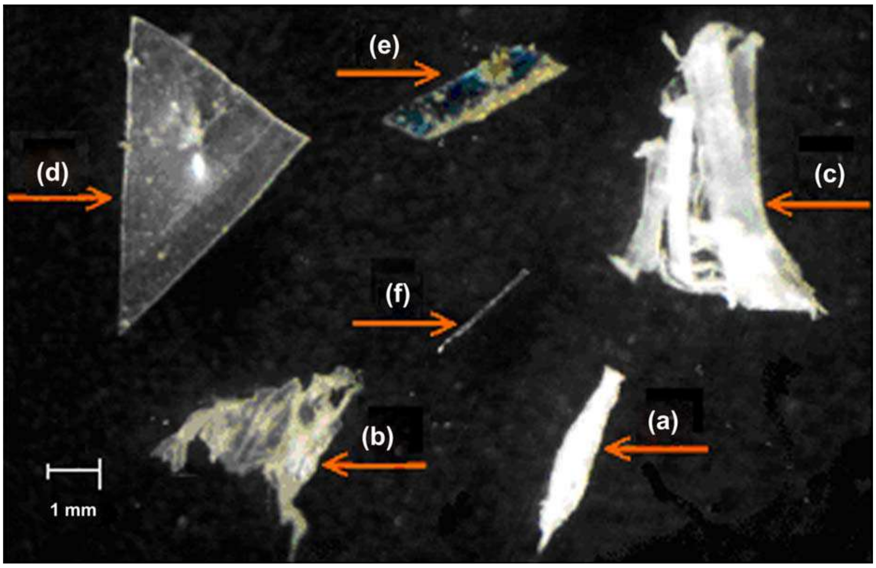

Figure1.Microscopic images of small plastic fragments in sediments of Alang-Sosiya ship-breaking yard. (a) Thermocol; (b) styrofoam; (c) nylon; (d) transparent; (e) colored plastic; (f) glass wool(Source: Reddy et al., 2006).

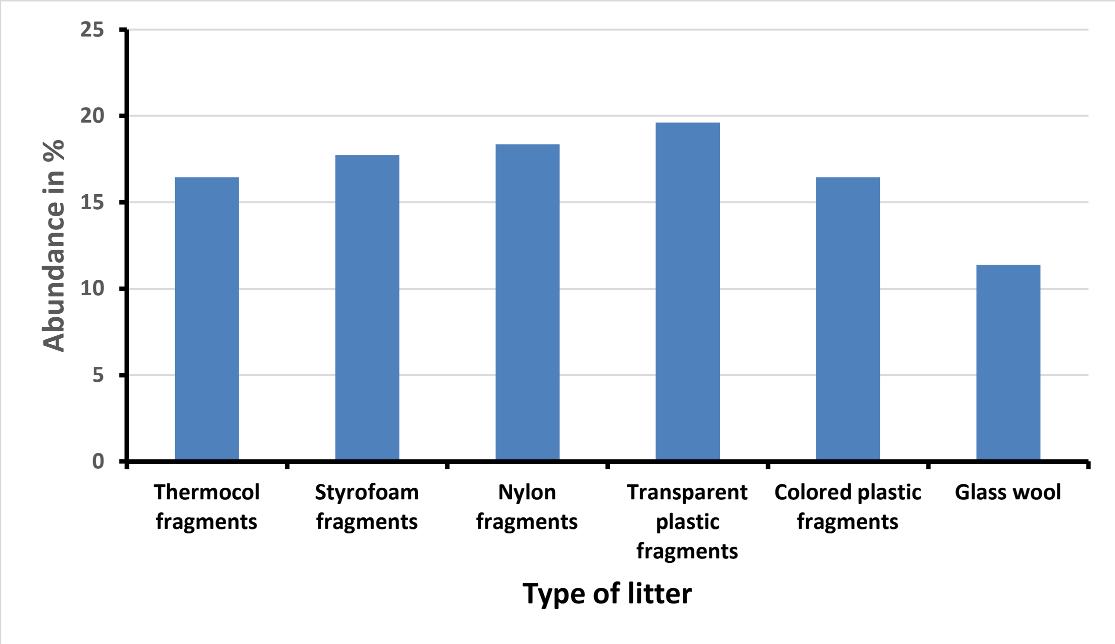

Figure 2.Abundance of small plastics in intertidal sediments of Alang-Sosiya ship-breaking yard in the year 2004 (Plotted based data from Reddy et al., 2006)

(ii) Mumbai coast, Maharashtra

Mumbai is the most populous metropolitan city on the west coast of India and the capital of the state of Maharashtra. The state of Maharashtra accounts for 653 km long coastline with 17% sandy beaches and many of these are lying within Mumbai city.

The abundance and distribution of plastic litter was quantitatively assessed in four sandy beaches in Mumbai, India by Jayasiri et al. (2013).Overall, average abundance of 11.6 items m^{-2} (0.25–282.5 items m^{-2}) and 3.24 g m^{-2} (0.27–15.53 gm^{-2}) plastic litter was recorded in Mumbai beaches. The coloured plastics were predominant with 67 % by number of items and 51 % by weight (Figure 3 & 4). More than 80 % of plastic particles were within the size range of 5–100 mm both by number and weight (Figure5). Probably, the intense use of beaches for recreation, tourism, and religious activities has increased the potential for plastic contamination in urban beaches in Mumbai.

Figure 3.Plastic items found in the beaches of Mumbai (a) Unidentified microplastics, (b) virgin plastic pellets, (c) plastic beads, (d) plastic fragments (Jayasiri et al., 2013).

(iii)Goa beaches

Goa State located on the central west coast of India is one of the most famous tourist spots in Asia, attracting nearly 4 million tourists every year because of its beautiful beaches, cultural heritage sites and associated recreational activities. Goa has a coastline of approximately 105 km. The economy of Goa mainly depends on tourism and population is 1.45 million according to the 2011Census data. The coastline of Goa is characterized by bays, headlands, creeks, promontories, sea cliffs, estuaries and world famous beaches. The recent study found that the distribution of microplastic pellets along the Goa coast, west coast of India are arrived at the coast mainly during the southwest (SW) monsoon, and whatever found during the northeast (NE) monsoon or other seasons are those reached on the coast during SW monsoon, but further undergone weathering processes, for example, colour changing from white to yellow due to exposure to sun (Veerasingam et al., 2016a) (Figure 6).

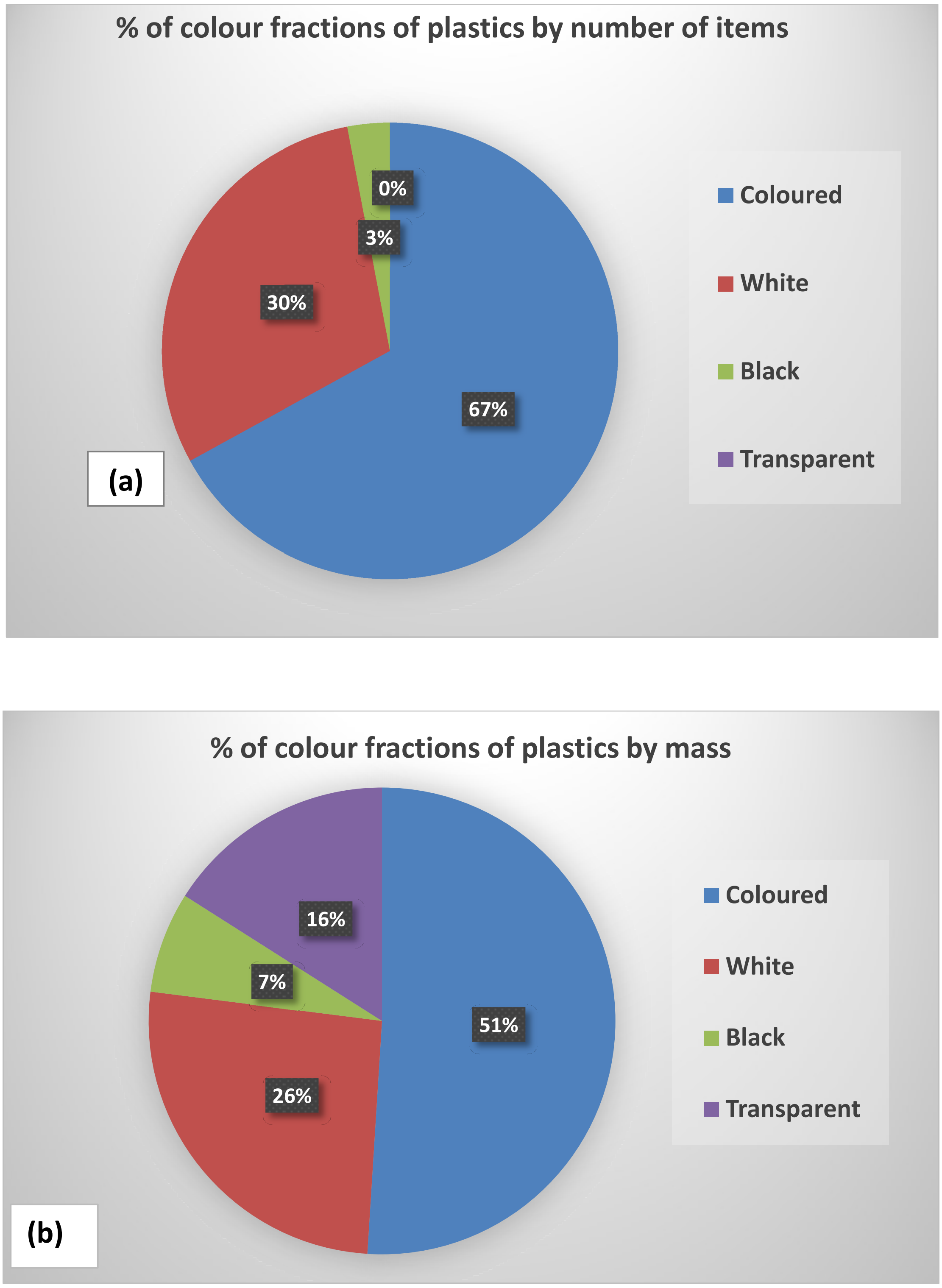

Figure 4. Average percentages of colour fractions of plastic debris in beaches of Mumbai coast: (a) by items and (b) by weight (Data Source:Jayasiri et al., 2013)

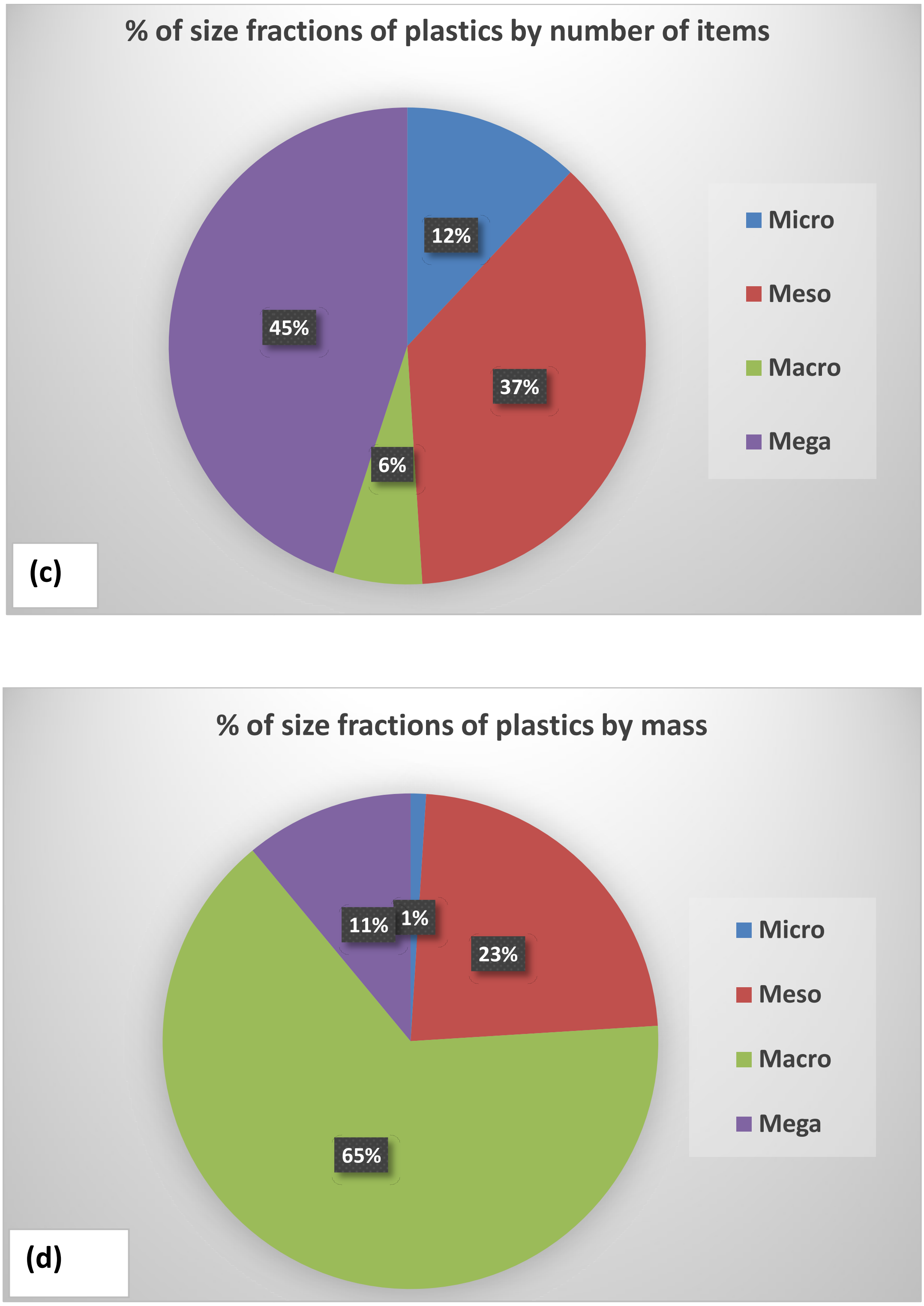

Figure 5. Average percentages of size fractions of plastic debris in beaches of Mumbai coast: (c) by items and (d) by weight (Data Source: Jayasiri et al., 2013)

The pellets collected during SW monsoon were white in colour with virgin surface, and these pellets are fresh with short residence time on the beaches. The pellets collected during NE monsoon were white-yellowish in colour with highly degraded surfaces and relatively longer residence time. White colour pellets were the most abundant, and Polyethylene (PE) and Polypropylene (PP) were the dominant polymer types of pellets deposited on all the beaches.

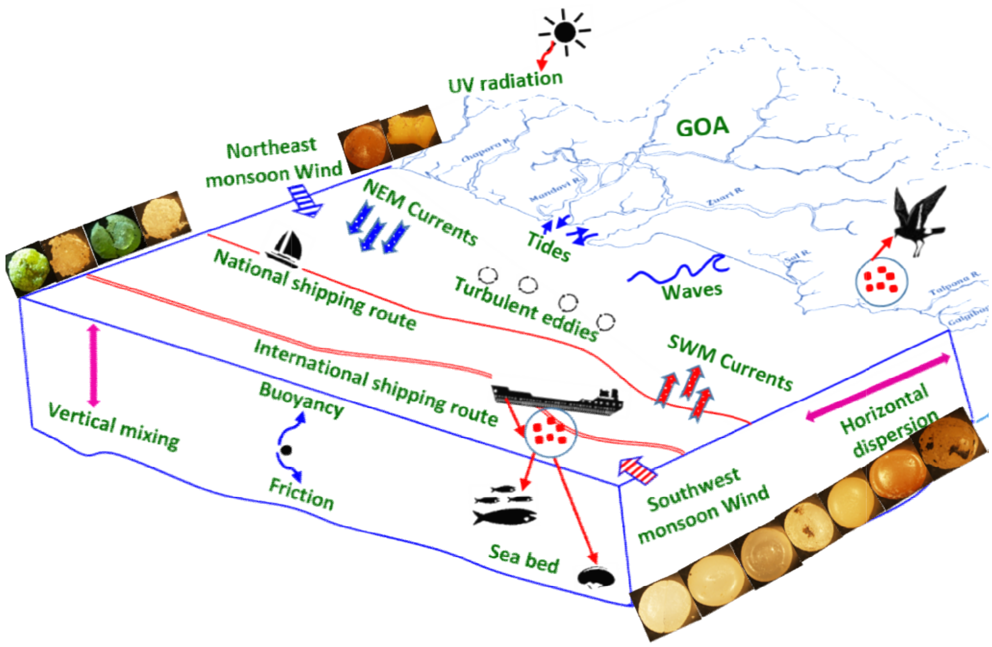

Figure 6.Schematic diagram for the sources and transport pathways of microplastic pellets along the Goa coast (Veerasingam et al., 2016a).

(iv) Mangalore beaches, Karnataka

The Mangalore coast is situated on the west coast of India, stretching to about 22 km of coastal district of Dakshina Kannada, Karnataka.The major rivers Nethravathi and Gurupur drain into the sea. These rivers originate at an elevation of 1400-1600 m.

Marine litter survey was conducted in the beaches of Mangalore by Sulochanan et al. (2014). Maximum total number and weight of marine litter was observed in Thannerbhavi (632 numbers /m^2) and Chitrapur (10,923.05g/ m^2) beaches respectively. Group of litter comprising nylon and plastic rope was the most abundant in the beaches(Figure 7).

Figure 7. Marine litter found along the Mangalore coast: (a) Fishing and abandoned net (b) Casting the Maranabale net(Sulochanan et al., 2014).

(v) Vembanad Lake, Kerala

Vembanad Lake is the largest brackish wetland ecosystem in the southern India, with an area of 151,250 ha. The major city of Kochi, 12 municipal towns and 100 villages are located on the bank of this lake. It receives an annual raninfall of 300 cm and an average annual inflow of 21,900 Mm^3 through its tributaries. The abundance of microplastics recorded from the sediment samples in the range of 96–496 particles m^{-2} with a mean abundance of 252.80 ± 25.76 particles m^{-2}. Low density polyethylene has been identified as the dominant type of polymer component of the microplastics (Sruthy and Ramasamy, 2017). As clams and fishes are the major source of protein to the local population, the presence of MPs in the lake becomes critically important, posing a severe threat of contaminating the food web of this lake (Figure 8).

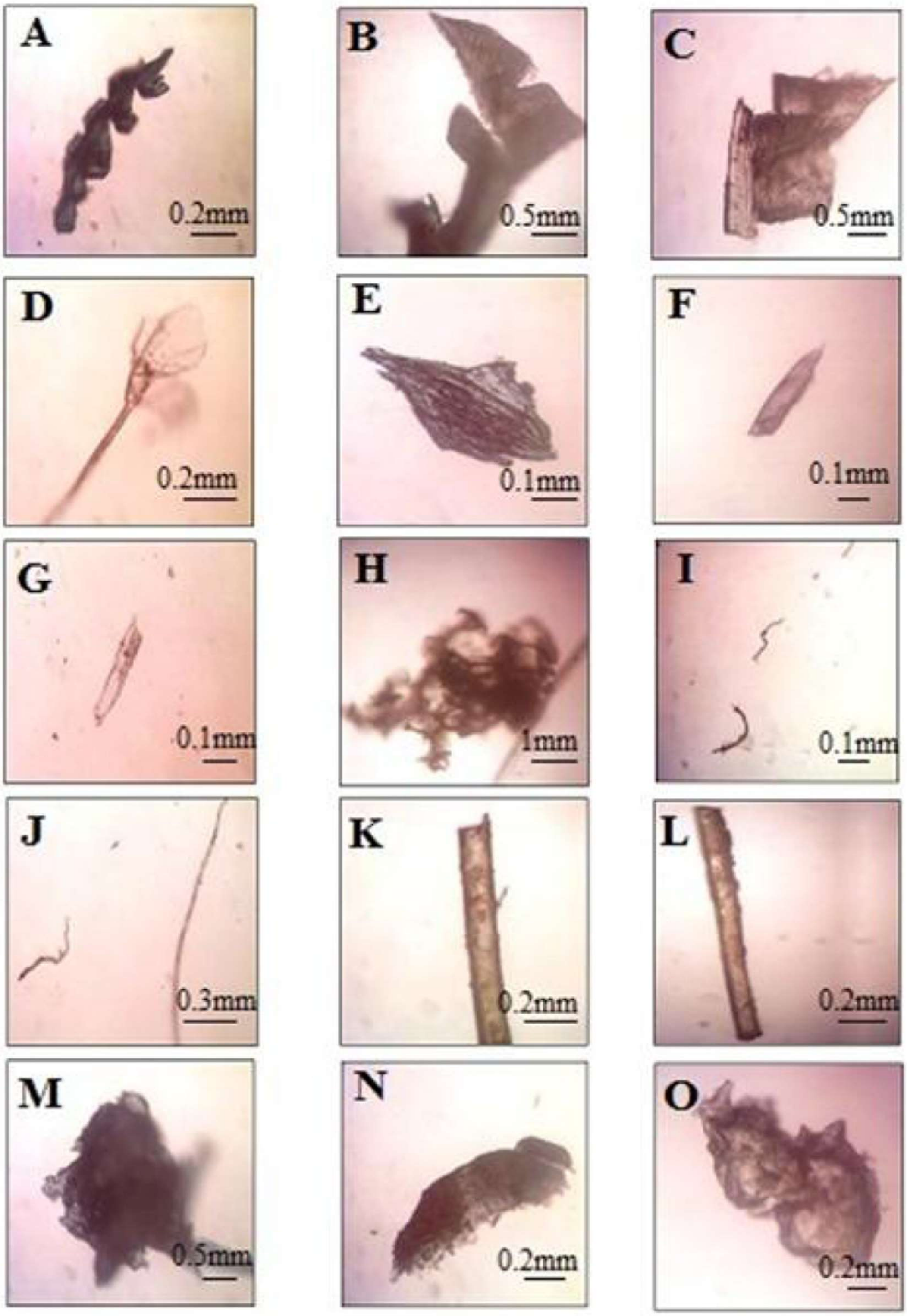

Figure 8.Miroplastics in sediments from Vembanad Lake. Particle type category: fragment (A–C), film (D–G), foam (H), fiber/line (I–L), and pellet (M–O) (Sruthy and Ramasamy, 2017).

(vi) Lakshadweep Islands

The Lakshadweep islands (36 islands, 10 inhabited) situated off the Kerala coast are made up of coral reefs of Holocene age. The plastic debris abundance was investigated in the Lakshadweep Islands (Agatti, Kavaratti, Bangaram and Tinnakkara) during the northeast (NE) and southwest (SW) monsoon season of 2014-2015 (Figure 9). A total of 10,778 (average abundance of 134.73 items m^{-2}) pieces of microplastics were found from four Islands, 20% of which was plastic resin pellets. The distribution of plastic debris in Lakshadweep Islands during the SW monsoon is higher than those found in NE monsoon season. Despite the remoteness of the island a considerable amount of plastic debris was present. In both monsoon season, the wind and current pattern are favorable to transport the floating debris from offshore regions to the coast and deposited on beaches of Lakshadweep Islands (Mugilarasan, 2016).

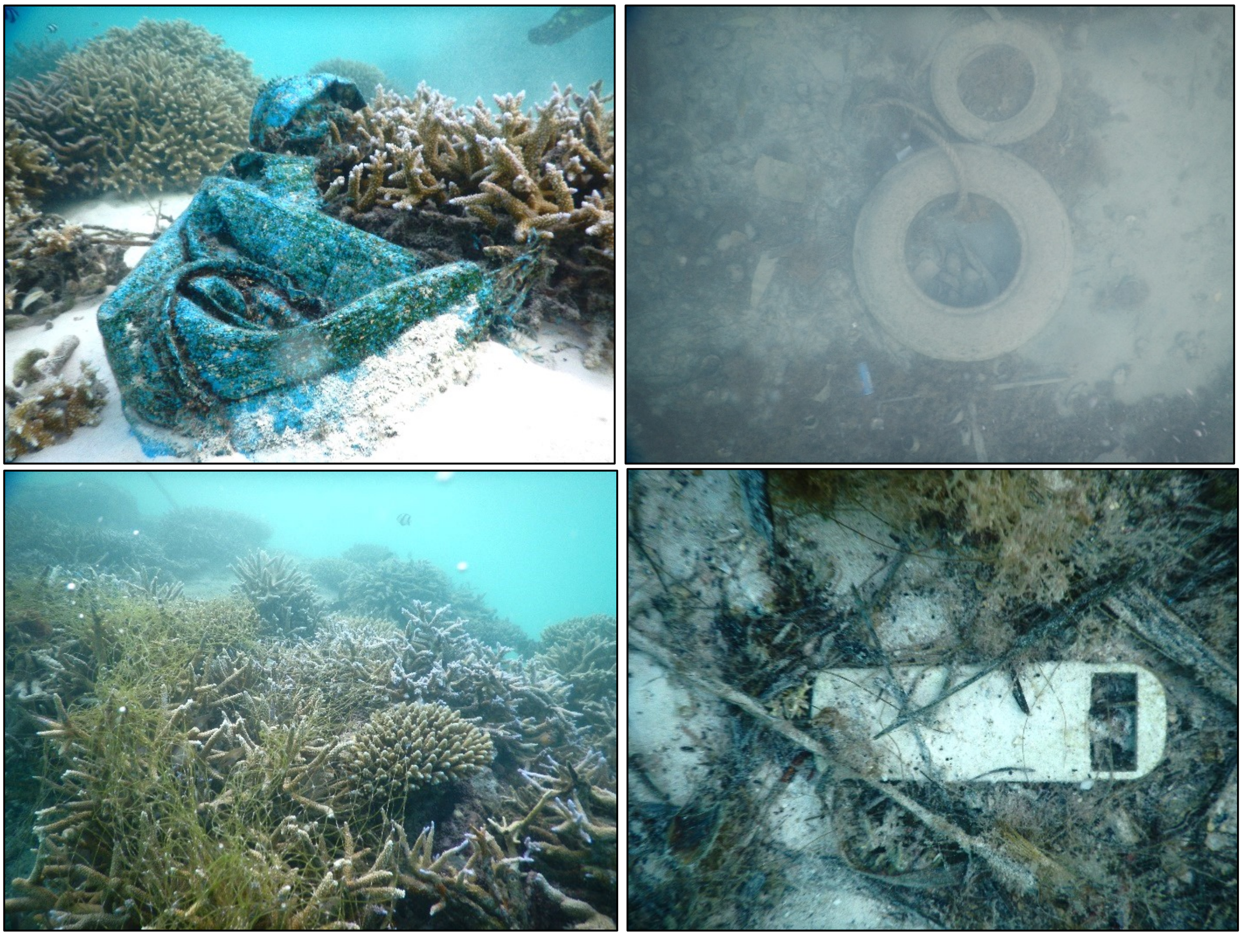

Figure 9.Marine litter found in coral reef Islands, Lakshadweep archipelago (Mugilarsan, 2016)

Mugilarasan et al. (2017) found that the total number of pellets collected from Chennai and Tinnakkara were 201 and 603 respectively. The number of pellets found in Tinnakkara

Island was three-fold more than those from the Chennai coast. Though Tinnakkara Island is located relatively remote oceanic areas and no plastic manufacturing activities found nearby, it is very closest to the international tanker route across the Arabian Sea. Therefore, the abundance of plastic resin pellets in Tinnakkara Island could be derived from international tanker route ship accident and/or unintentional release and deposited by hydrodynamics.

East Coast of India

(i) Gulf of Mannar, Tamil Nadu

The Gulf of Mannar is situated at southeast coast of India and it is referred as the Biologist's paradise because of the rich marine ecosystem (nearly 3600 species of living flora and fauna). It is unique because of the presence of coral reefs, seagrass beds and mangroves, which act as spawning and feeding grounds and as shelter for many species of economically important finfish and shellfish.

The distribution, abundance, composition and quantification of the types, amount, sources and impact of marine litter on the beach of the Gulf of Mannar region was studied by Ganesapandian et al. (2011). Occurrence of shoreline marine litter during the southwest monsoon period was the maximum and the cool winter period was the minimum (Figure 10). The maximum shoreline litter was 94–95 items of 5409-6588 g and the minimum shoreline marine litter was 42 items of 2088g. Three major marine litter items such as plastic (48%), polystyrene (18%) and cloth (15%) were found. Fishing represented the largest source, tourism/recreation was the second and Sewage related debris was the third common source of marine litter.

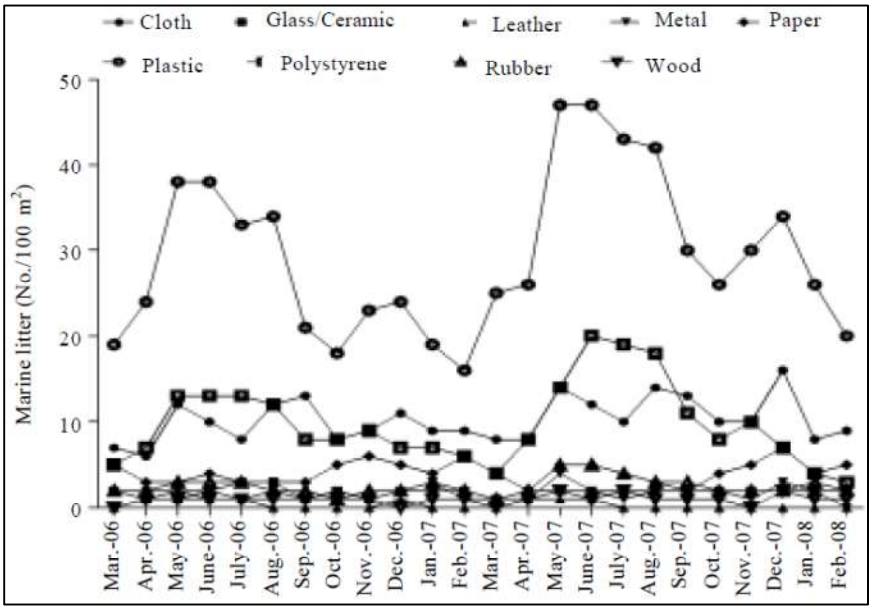

Figure 10. Month-wise quantity of shoreline marine litter in the northern Gulf of Mannar (Ganesapandian et al., 2011).

(ii) Chennai coast, Tamil Nadu

Chennai metropolitan is located on the southeast coast of India with 56 km coastline and is the capital city of Tamil Nadu state. Chennai is the fourth most populous metropolitan area and the sixth most populous city in India with an estimated urban agglomeration of over 8.6 million people. Two major rivers meander through Chennai: the Cooum River through the center and the Adyar River to the south.

The sources, distribution, surface features, polymer composition and age of microplastic pellets (MPPs) in surface sediments along the Chennai coast during March 2015 (pre-Chennai flood) and November 2015 (post- Chennai flood) were studied by Veerasingam et al. (2016b). White MPPs were the most abundant, and specifically Polyethylene (PE) and Polypropylene (PP) were the dominant polymer types of MPPs found on the coast during both the times. The abundance of MPPs in November 2015 was three fold higher than those found in March 2015, confirming that huge quantity of fresh MPPs washed through Cooum and Adyar rivers from land during the flood. The winds and surface currents during November were the driving forces for the transportation and deposition of MPPs from the sea to beaches (Figure 11a-e).

(iii) Marina beach, Tamil Nadu

The Marina beach in the southeast coast of India is the most crowded beach in the country and attracts about 30,000 visitors a day during weekdays and 50,000 visitors a day during the weekends and holidays. During summer months, about 15,000 to 20,000 people visit the beach daily. This beach is extensively used for recreational uses such as swimming, surfing and picnicking generates debris such as food wrappers, plastic bags and cups, trash bags, product containers, toys and floats.

Marine litter was collected on four occasions between March 2015 and April 2015 from 10 transects, each 5m wide and 100m long, sorted and categorized by type, quantity and concentration rate along the coastline by Arunkumar et al. (2016). The results indicated that the plastic, paper and wood litter occur in the greatest number followed by food waste and metal. The major contributing factor for the debris abundance in Marina beach is the local recreational activity which suggests that the land-based sources provide major inputs to marine litter pollution at beach (Figure 12).

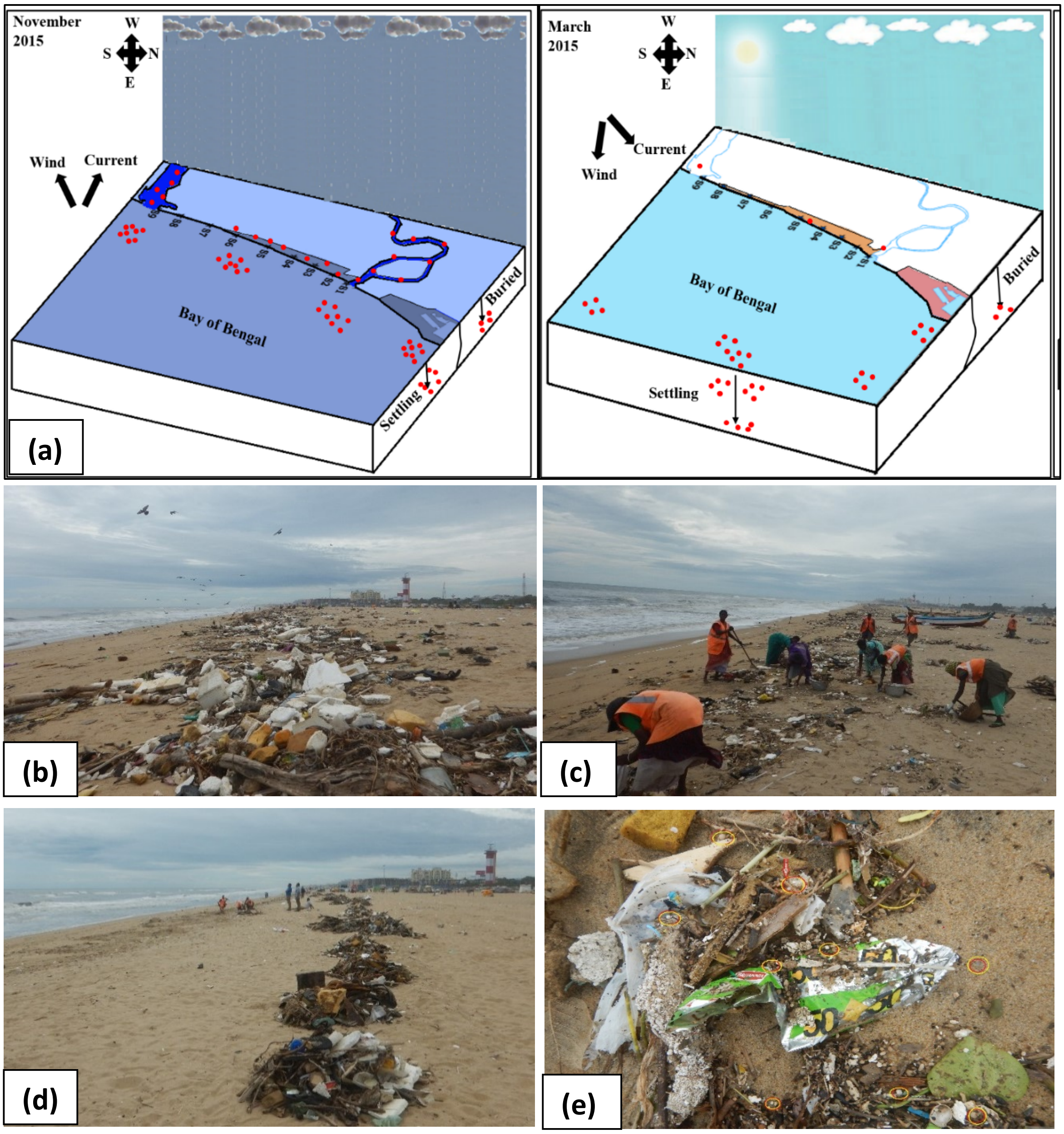

Figure 11 (a) Schematic diagram depicting the driving forces, transport processes and possible sources of MPPs during pre-flood (March) and after post-flood (November) along the Chennai coast (Red dot share the MPPs). (b-e) the deposition of debris along the Chennai coast during 2015 flood (Veerasingam et al., 2016b).

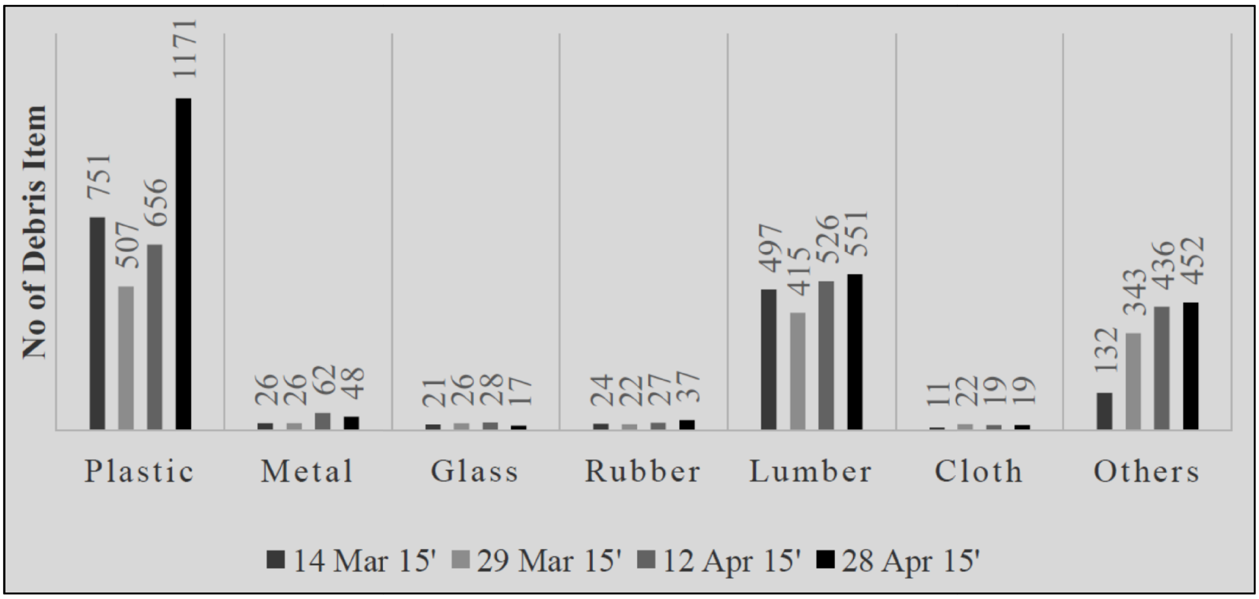

Figure 12.Composition of marine litter collected on the Marina beach (Source: Arunkumar et al. 2016)

(iv) Chilika lagoon, Odisha

Chilika Lake is the Asia's largest brackish water lagoon situated in Odisha along the Indian east coast. It is one of the biodiversity hotspots and a good source of fishery in coastal wetlands of the entire east coast. Its Nalaban Island bird sanctuary serves as a wintering ground for thousands of migratory and resident birds every year. It is also one of the few lagoons in the world which supports congregation of Irrawaddy dolphins.

Plastic litters are entering into the Chilika lagoon from many different sources (Figure 13). These include plastic waste of domestic and industrial origin through rivers and rivulets debouching freshwater into the lake and dumping of damaged plastic nets and net residues used in 'gheri' culture (pen culture). Of late, dumping of plastic materials like bottles, packing materials, water pouches, carry bags, etc. has aggravated the situation The villages surrounding the lagoon have no proper waste disposal and management system, which promotes the addition of residual plastic into the lake system (Sahu et al., 2013).

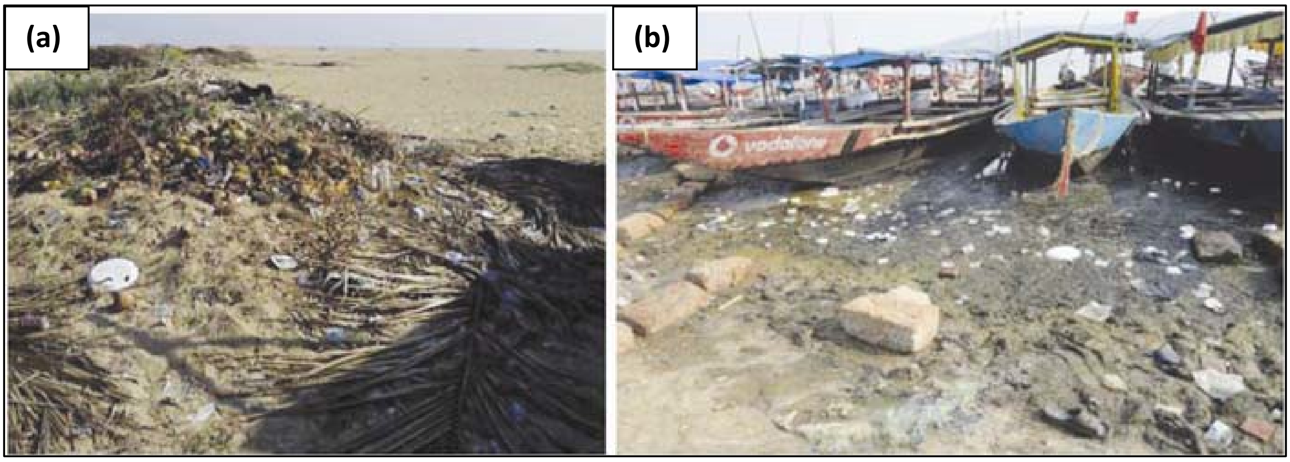

Figure 13. Plastic litter in Chilika lagoon. (a) near Sipakuda inlet (the eastern region of the lagoon) and (b) Barkul jetty (western region) (Sahu et al., 2013).

(v) Andaman and Nicobar Islands

Andaman and Nicobar Islands are situated off the eastern coast of India in the Bay of Bengal and are also called Bay Islands. The islands, which have proximity to some of the South East Asian countries like Myanmar, Thailand, Malaysia, Singapore and Indonesia, comprise 572 islands, islets and exposed rocks. The island coast extends to 1912 km, which is almost one-fourth of the Indian coastline.

Sea-surface current prevailing in that region might have resulted in debris being circulated continuously in the open sea and coastal areas, and subsequently washed ashore in Andaman coastal areas. From the above observation, it may be inferred that the garbage generated in the coastal areas of Sumatra, Singapore, Malaysia, Indonesia and other South East Asian countries and by international shipping services is not disposed properly and dumped directly into the sea (Dharani et al., 2003). This is taken by the currents and washed ashore on our pristine beaches of the Great Nicobar and Nancowry group of islands. Apart from this foreign plastic invasion through oceanic circulation, plastic and glass find several ways, like our domestic materials, to enter into our pristine islands and subsequently into the coastal ecosystem, since there is no proper solid-waste disposal practice (Figure 14).

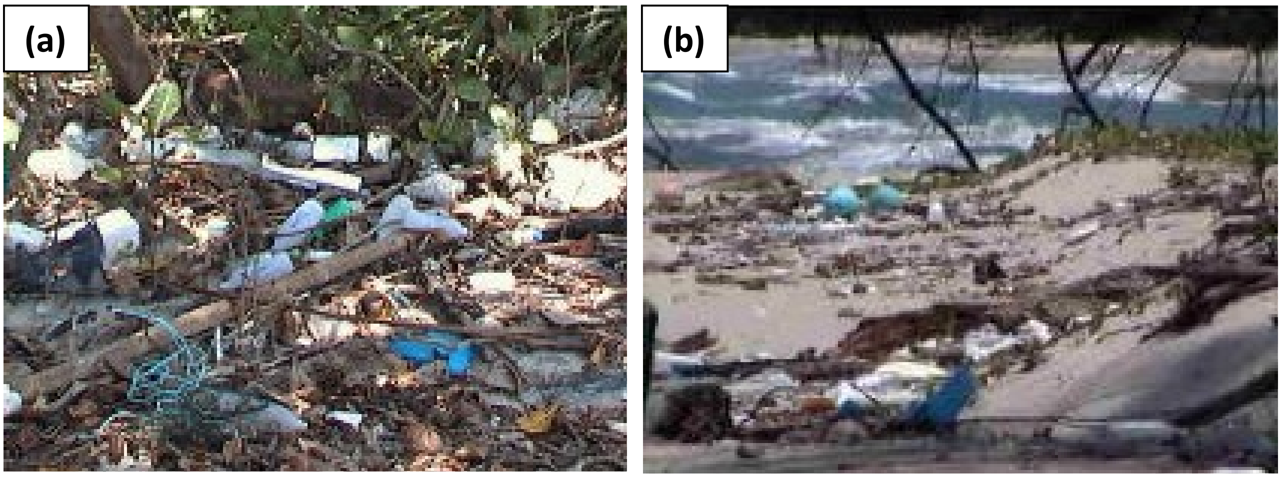

Figure 14 Plastic debris observed on the beaches of Andaman & Nicobar Islands
(a) Plastic debris and (b) fishing buoys (Dharani et al., 2003).

Prevalence of marine litter along the Indian beaches:

Synoptic picture of status and composition of beach litter from 254 selected beaches along the maritime States of Peninsular coast of India as well as the Union Territories of Andaman and Lakshadweep Islands from the one time observation conducted between October 2013 and January 2014 (Kaladharan et al., 2017). Beach litter from different maritime States and the UTs showed that Odisha coast has the lowest (0.31 g/m^2) quantity and Goa coast (205.75 g/m^2) the highest quantity of beach debris.

Archipelagic coasts of Andamans as well as Lakshadweep recorded values higher than Kerala, Tamil Nadu, Andhra Pradesh, Odisha and West Bengal. Samples of debris collected from beaches revealed that all the items were domestic and anthropogenic discards. Plastic litters such as single use carry bags and sachets of soft drinks, edible oils, detergents, beverages, cases of cosmetics, toothpaste, PET bottles, ice cream containers etc., recorded highest mean of 25.47g/m^2 from Goa coast and the lowest (0.08g/m^2) from Odisha (Figure 15).

In Indian Ocean, the Northern Equatorial Current and North Equatorial Counter Current system have carried the marine litter from the Indian sub-continent, Southeast Asia, and the countries on the Arabian Sea and deposited on an isolated coral atolls in the West Indian Ocean.

Bouvman et al., 2016 identified Southeast Asia, the Indian sub-continent, and the countries on the Arabian Sea as most probable source areas of 50,000 items on the shores of St. Brandon's Rock (SBR), Indian Ocean. 79% of the debris was plastics. Flip-flops, energy drink bottles, and compact fluorescent lights (CFLs) were notable item types. The density of debris (0.74 m^{-1} shore length) is comparable to similar islands but less than mainland sites.

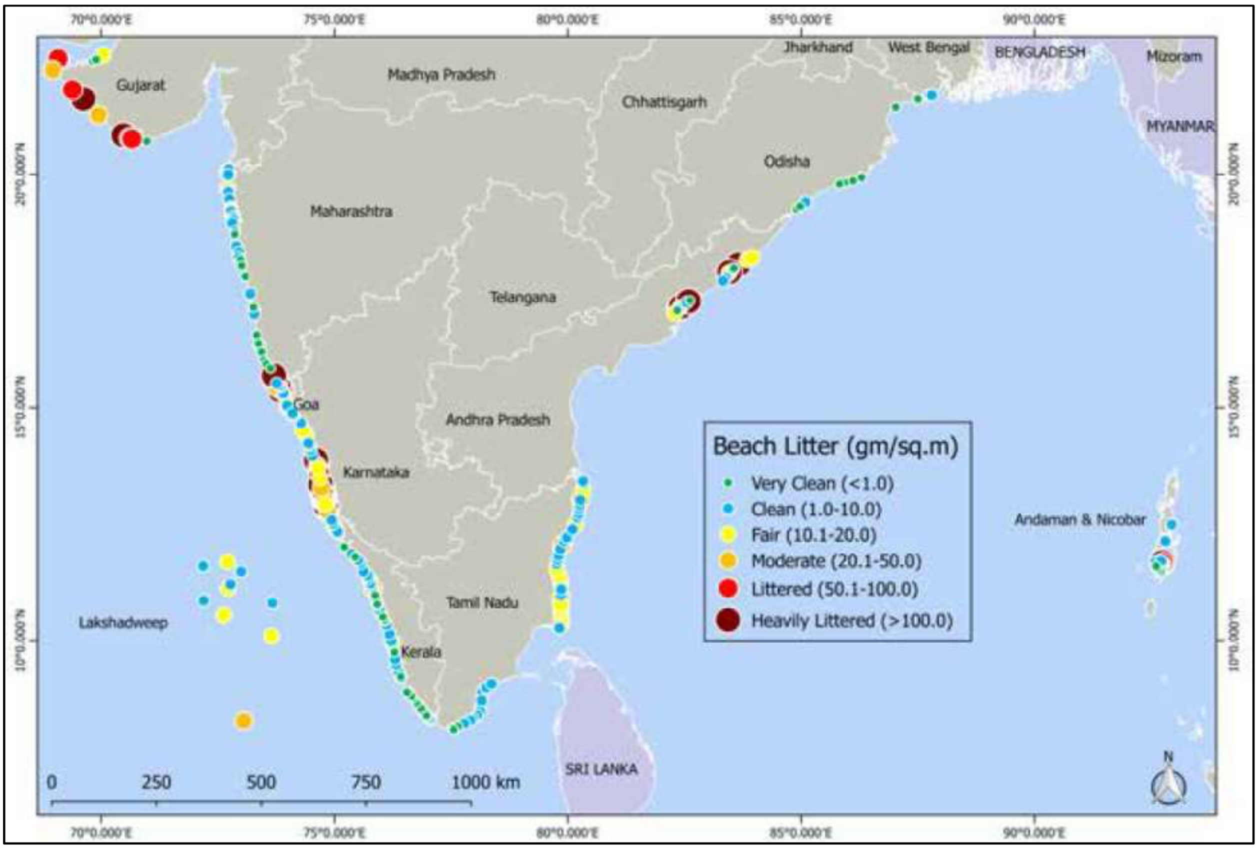

Figure 15.Marine litter status along Indian beaches during October 2013- January 2014 (Source: Kaladharan et al., 2017)

Bay of Bengal, Northeast Indian Ocean

Ryan (2013) found that the densities of floating litter (>1 cm) were greater and more variable in the Straits of Malacca (578 ± 219 items km^{-2}) than in oceanic waters of the Bay of Bengal (8.8 ± 1.4 items km^{-2}). In the Bay of Bengal, debris density increased north of 17ºN mainly due to small fragments probably carried in run-off from the Ganges Delta. The low densities in the Bay of Bengal relative to model predictions may result from biofouling-induced sinking and wind-driven export of debris items.

In the Bay of Bengal, Eriksen et al. (2018) found 41% fragments and 40%Film. This observation of more plastic film in the Bay of Bengal may be a reflection of coastal population density and their usage of thin film in the form of plastic bags. According to Lebreton et al. (2017) the Ganges River is the 2nd largest emitter of plastics to the marine environment, and in this study the Bay of Bengal samples had 10 times more plastic particles than the South Pacific.

Tar ball deposition along the west coast of India

Deposition of tar balls along the west coast of India,particularly Goa and Gujarat coasts, is a commonphenomenon; it occurs only during pre-monsoon tosouthwest monsoon season every year (Figure 16).Based on chemical fingerprinting analysis (Figure 17) and mathematical particle trajectory models (Figure 18) it is found that the sources of tar ball deposition along the west coast of India are leakages in offshore oil fields off the Mumbai–Gujarat coast and accidental spillages during the transportation of crude oil in the Arabian Sea (Suneel et al., 2013, 2014, 2016)

Figure 16. Deposition of tar balls on the beach of Goa (a) is on 02/09/2010at Candolim, (b) is on 25/05/2011 at Mandrem, (c) is on 26/05/2013at Mobor, (d) is on 08/06/2014 at Candolim, (e) is on 05/06/2015at Benaulim, (f) is on 23/03/2016 at Majorda beaches (Source: Suneel et al., 2013).

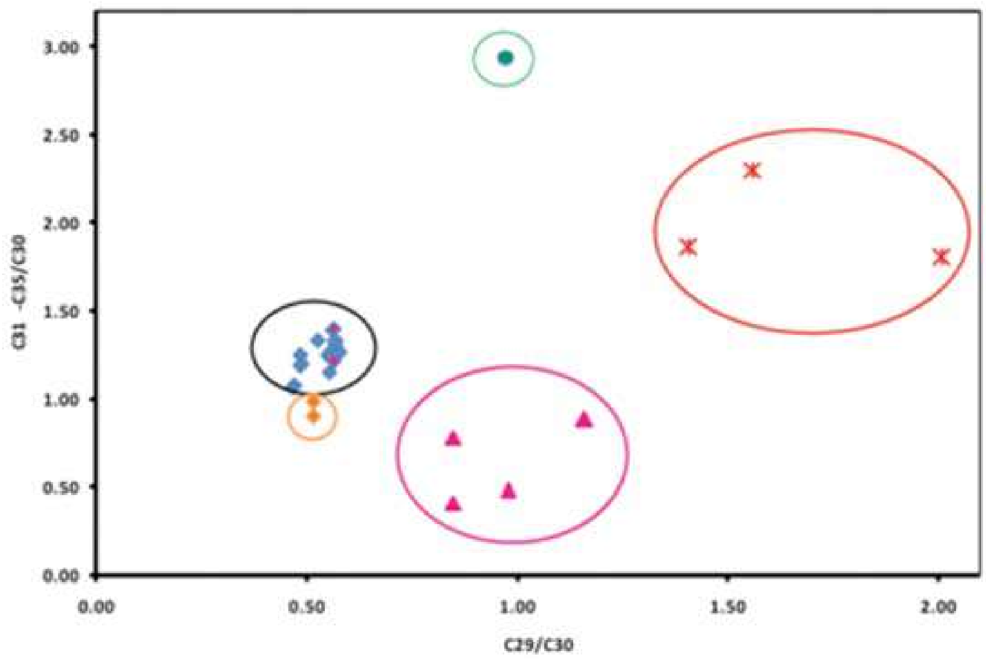

Figure 17. Cross plot of homohopane index. The red circlerepresents Middle East Crude Oil, pink-south East Asian CrudeOil, orange-Cairn and Niko oil, green-MSC Chitra crude oil;black circle represents tar balls of Gujarat coast (blue color)and Bombay High Hut (pink color top) and Bombay High Mut(pink color down) (Source:Suneel et al., 2014).

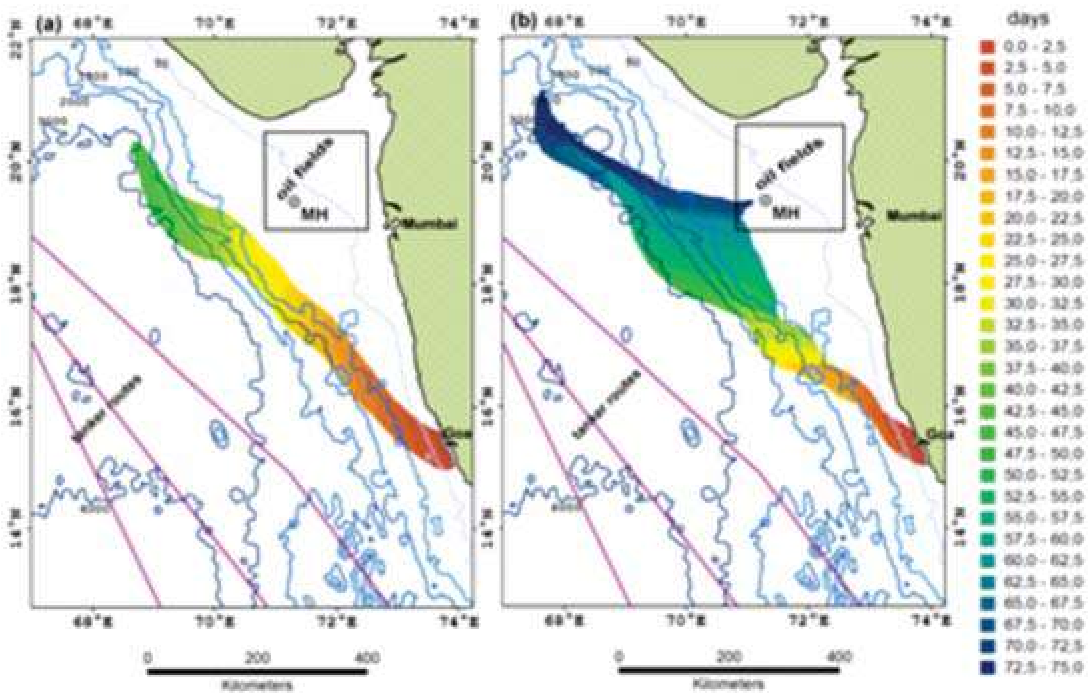

Figure 18. Trajectories of tar balls using backtracking simulation for May 2013 and 2014 (Source: Suneel et al. 2016).

2.4 Sources (through rivers and canals, dumping by ships and boats, surface drainage and other sources such as tourists, wind, etc.)

Jambeck et al. (2015) estimated that between 4.8 and 12.7 million tons of land-based plastic waste ends up in the ocean every year. Of the top 20 countries releasing waste into the oceans, 10 have shores on the Indian Ocean, the third largest ocean in the world (Figure 19). The recent study showed that between 1.15 and 2.41 million tons of plastic waste currently enters the ocean every year from rivers, with over 74% of emissions occurring between May and October (Lebreton et al., 2017). The top 20 polluting rivers, mostly located in Asia, account for 67% of the global total (Figure 20).

Shipping represents a continuing source of marine litter, both due to accidental release (collisions, storm damage) and illegal disposal of plastics at sea, in breach of Annex V of the MARPOL convention. Shipping accounts for approximately 90% of global trade. The introduction of containerised cargo handling in the 1960s brought about a step-change increase in the efficiency and decrease in the cost of shipping goods.

The change was pioneered on busy routes between North America and Europe, where the high capital investment was offset by a reduction in high labour costs, and gradually spread to developing economics, especially in Asia (Figure. shipping routes). There has been a tendency to increase capacity by building larger vessels. There has been a great expansion of trade in manufactured goods from Asia to Europe and North America, a significant fraction being composed of plastics, with most being transported by container vessels.

The number of containers lost each year is disputed, but was reported by the World Shipping Council (2014) to be approximately 550 per annum on average, not counting catastrophic losses (regarded as losses of >50 containers in one incident). The impact of major accidental losses can be significant locally. The pattern of shipping accidents roughly correlates with shipping traffic density (Butt et al., 2011).

Shoreline surveys adjacent to busy shipping routes (Figure 21), such as Lakshadweep islands, reveal a higher proportion of shipping-related debris (Mugilarasan et al., 2017). Some of this material may be casually thrown overboard, but some arises from accidental losses.

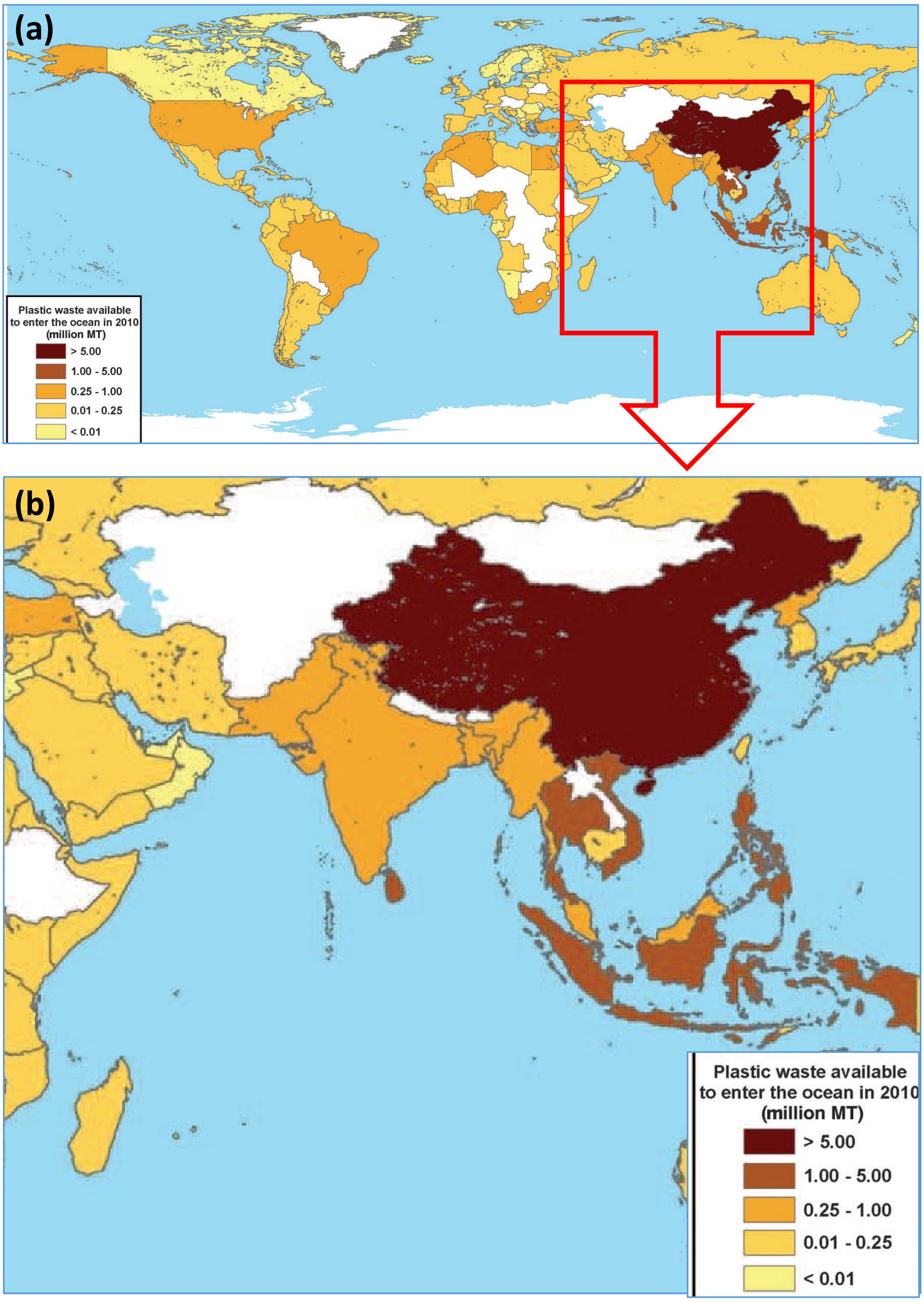

Figure 19. Global map showing the estimated mass of mismanaged plastic waste [millions of metric tons (MT)] generated in 2010 by populations living within 50 km of the coast (Source: Jambeck et al., 2015)

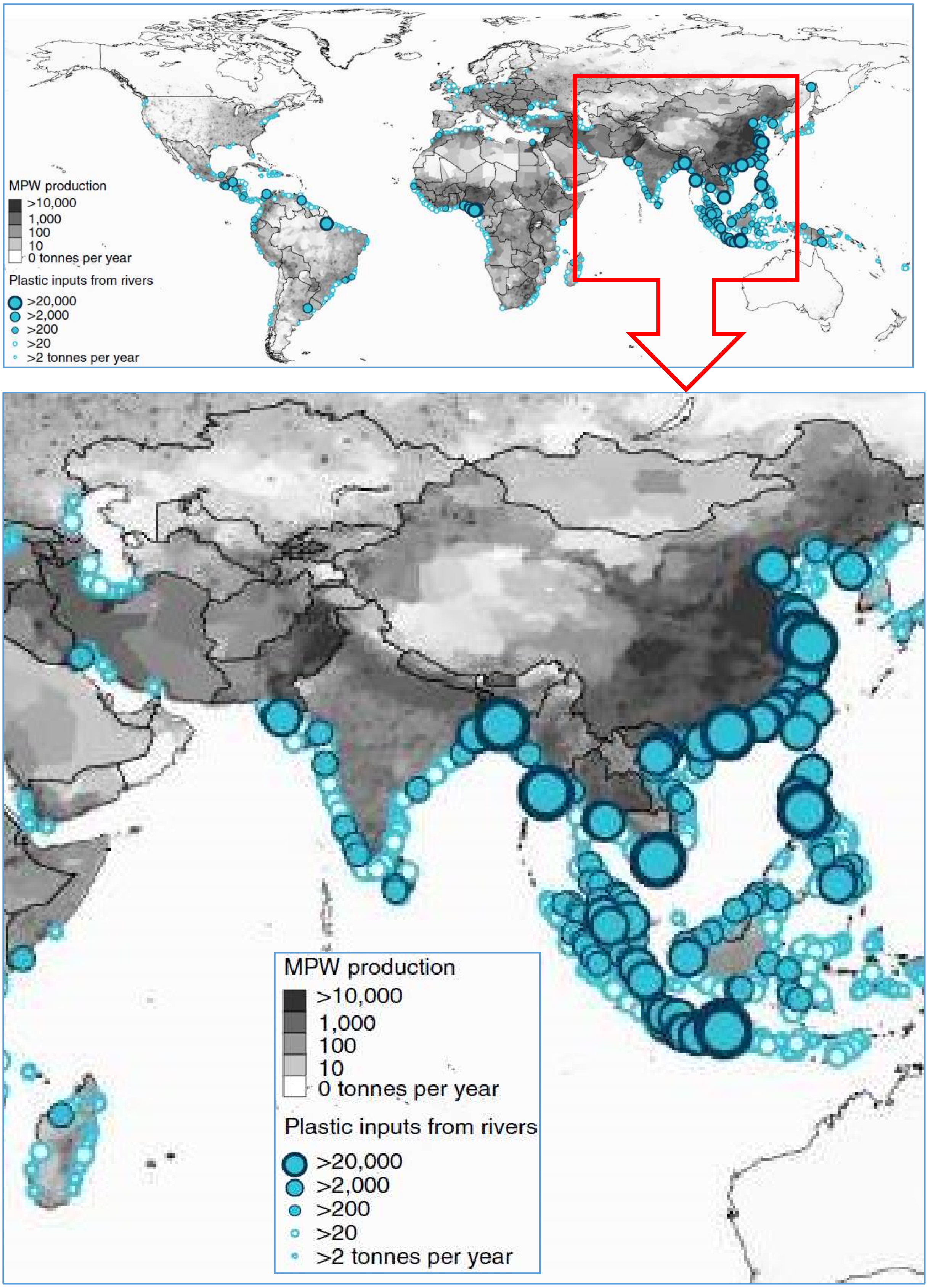

Figure 20. Mass of river plastic flowing into oceans in tonnes per year (Source: Lebreton et al., 2017)

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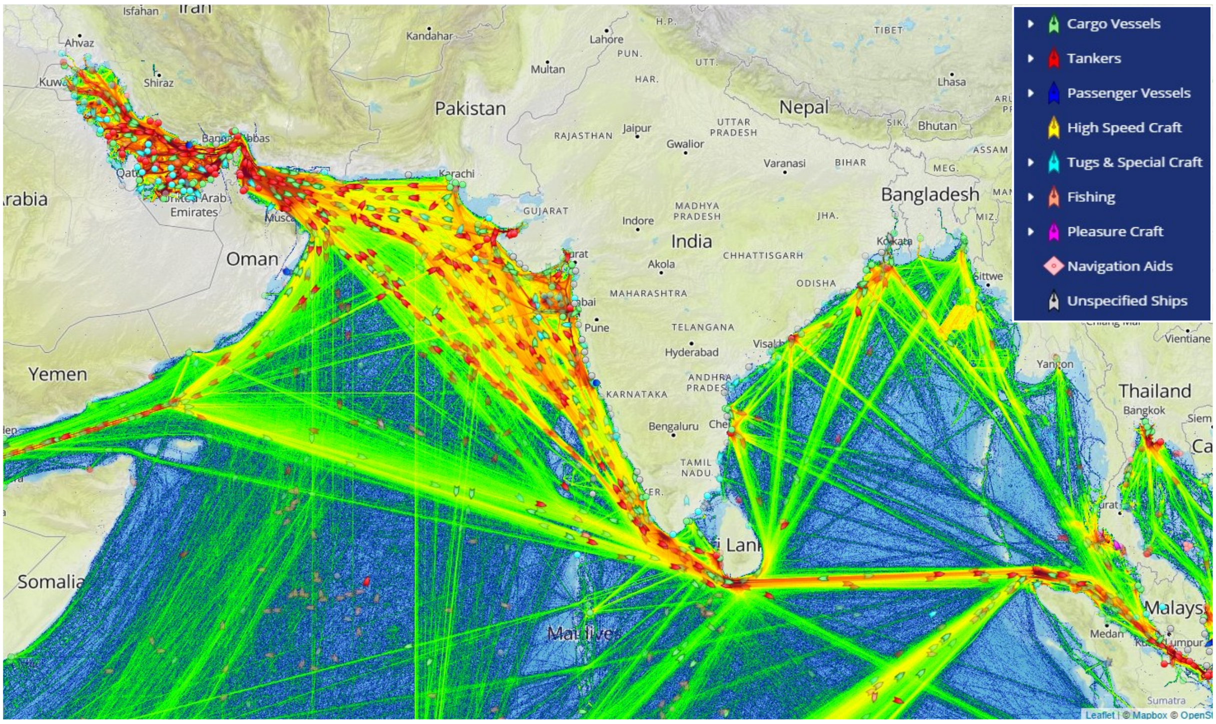


Figure 21. National and international tanker routes (Source: Automatic identification system (AIS) vessel tracking map)

3. CIRCULATION OF MARINE LITTER

3.1 Marine litter circulation

The circulation of the surface waters of the ocean are characterized by a broad pattern of persistent surface currents. These tend to dominate the passive transport of any floating marine litter. The ocean circulation is driven by the complex interaction of atmospheric forcing (winds), the Coriolis force due to the Earth's rotation, density differences (temperature and salinity) and deep-water formation in Arctic and sub-Arctic seas and Southern Ocean (Thermo-Haline circulation due to the sinking of cold, dense water, produced through the formation of freshwater ice). In coastal regions river outflows will influence currents at a more local scale. Within these broad patterns the circulation is highly complex and variable, on multiple scales in space (mm – 100s Km) and time (s – decades). This will have a significant influence on the distribution of floating litter, providing an explanation for some of the spatial and temporal variability in concentrations that have been observed. The water column is not uniform in temperature and salinity. The upper few meters of the ocean will be mixed by wave action episodically. Attempts to measure and interpret the distribution and abundance of floating litter in the surface ocean need to be placed in the context of this natural variability (UNEP, 2016).

The ocean can be divided into five compartments: Coastline, Surface/upper Ocean, the main water column, the seabed and biota (Figure 22). Marine litters (especially plastics) occur in all five compartments, and there will be processes acting both within and between compartments which will affect the fate and distribution of the plastic material. Plastics that are inherently buoyant (e.g. PE) can be expected to remain in the upper ocean, unless there is a change in density, for example by the attachment and growth of sessile organisms. The degree to which this may occur is unknown. Other plastics are denser than water so may be expected to occur on shorelines and the seabed. This difference in physical properties clearly will have a considerable influence on both the observed and modeled distributions. Plastics of all types may be found in the biota compartment (GESAMP, 2016).

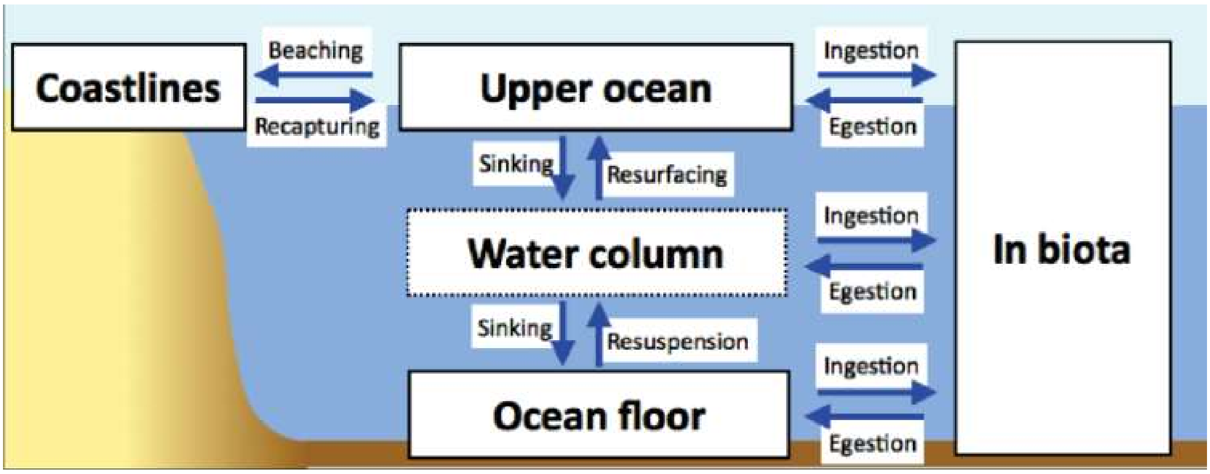


Figure 22. The fluxes of marine litter in various compartments of ocean (Source: GESAMP, 2016)

The degree of transfer of plastics between these compartments is largely unknown. Transfer of material on and off shorelines is likely to be considerable in some regions but often episodic, in response to wave action, wind and rainfall events, the proximity of sea- and land-based sources and the exposure of the coastline. Non-buoyant plastic objects (e.g. fishing nets) that are supported by buoyant objects (e.g. fishing floats) will continue to float in the water column or Upper Ocean until the buoyancy becomes ineffective then will sink to the seabed. Transport from the near-shore environment to the deep seabed may be facilitated by the presence of canyons and debris slides. Material may behave differently once fragmented. The relative importance of such transfers will be regionally dependent.

3.2 Land based sectors generation (Micro and Macro)

Modelling can provide a means to investigate the relative importance of different sources, where more accurate data is absent. Lebreton et al. (2017) used this approach to generate the relative contribution of floating plastics from three sources, based on proxy indicators: coastal population density, proportion of urbanized catchment (i.e. liable to more rapid run-off) and shipping density. The authors simulated the resultant distribution of plastics in coastal and open ocean waters using an ocean circulation model, into which particles could be introduced in proportion to the three indicators. The distributions were spatially resolved to fit the outlines of the 64 Large Marine Ecosystems (LME) and then placed in five categories of relative abundance. Figure shows the distribution ofmicroplastics by LME, with concentrations varying from highest to lowest in the order red-orange-yellow-green-blue. Highest concentrations occurred in SE Asia, around the Korean peninsula, the Bay of Bengal and the Mediterranean. This is consistent with the available observations (Figure 23).

The numerical modelling study (UNEP, 2016) simulated the distribution of floating plastic based on the estimated influx of plastic due to inadequate waste treatment, as defined by Jambeck et al. (2015).Figure 24 shows the simulated distribution of floating plastics originating from countries in SE Asia, indicating significant transboundary transport across the Bay of Bengal.

It can be difficult to assign how long plastic debris has been in the ocean and where it has come from, but models can be very useful in indicating probable transport pathways and the average time taken from source to sampling site (UNEP, 2016) (Figure25).

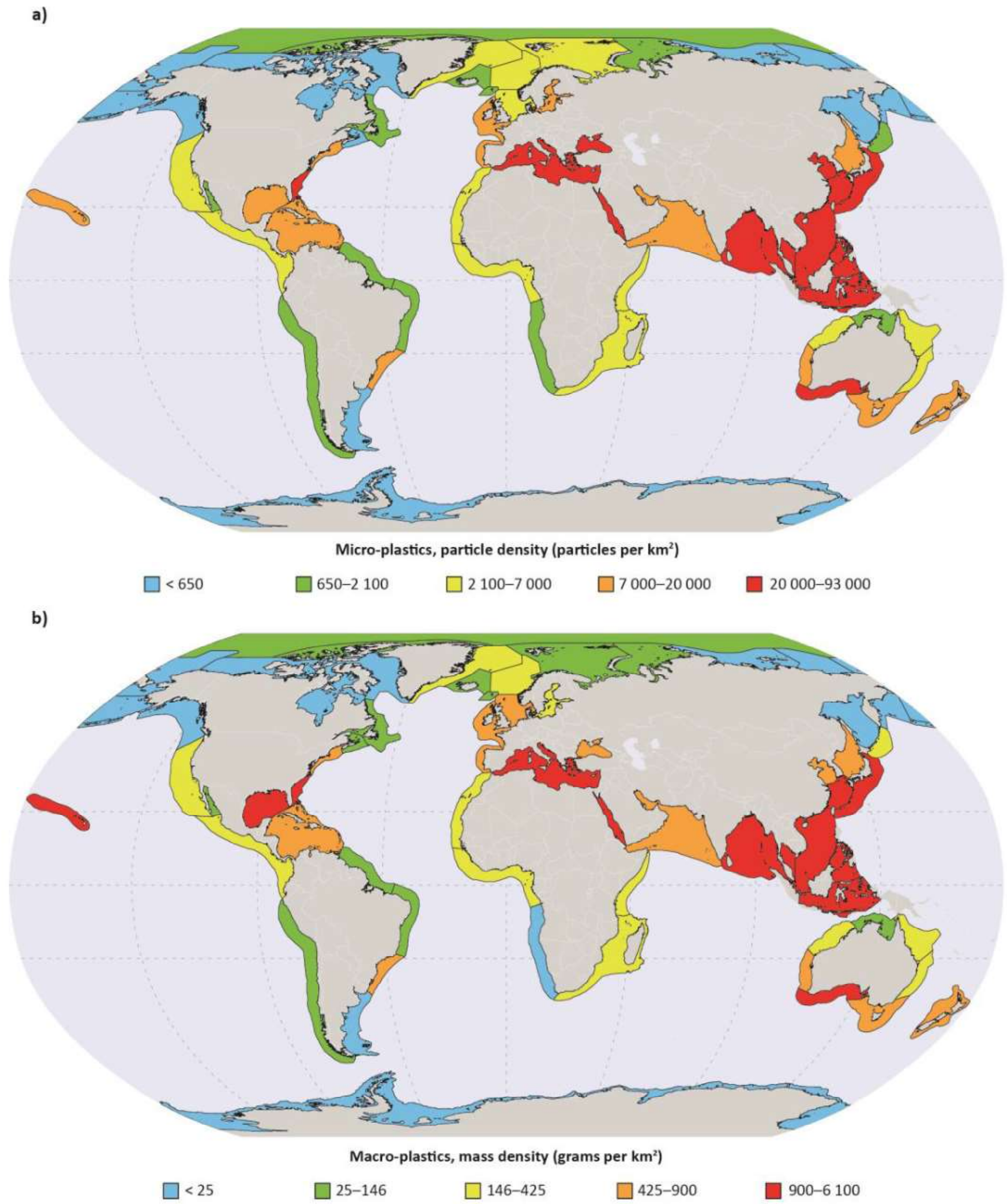


Figure 23. Estimated relative distribution of micro and macroplastic abundance in 64 Large Marine Ecosystems, based on Lebreton et al. 2012. Inputs of plastic ‘particles’ in the model were based on three proxy indicators of probable sources: coastal population density, proportion of urbanised watershed and shipping density. Concentrations were divided into five equal-sized categories of relative concentration, varying from highest to lowest in the order red-orange-yellow-green-blue. (GESAMP 2015).

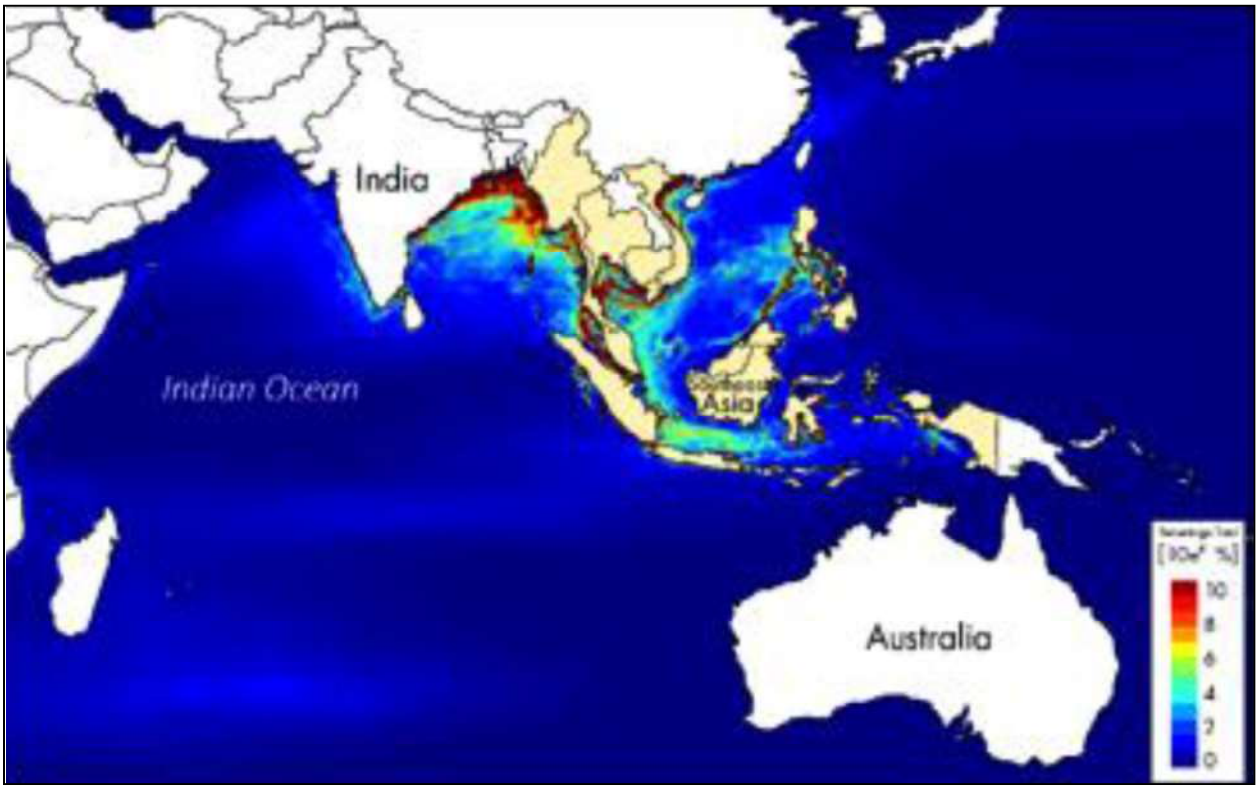


Figure 24.Simulated distribution of floating plastic in the coastal waters of SE Asia. This showing high concentrations in coastal waters, using as the source term the estimated influx of plastics from SE Asia due to ‘mismanaged waste’(Source: UNEP 2016).

Despite the increasing number of sampling expeditions, the total number of observations of floating macro and microplastics is rather small, and large areas of the ocean have not been sampled at all, particular in the Arctic, South Pacific, Indian Ocean and the Southern Ocean. It is possible to generate budgets of ocean plastics on the basis of model simulations, but these need to be validated by observational data. Eriksen et al. (2014)collated data on the number and mass of floating plastic particles/items from 24 expeditions (2007 – 2013) (Figure 26). These covered the five ocean gyres, the Mediterranean, Bay of Bengal and Coastal waters of Australia, combining surface net tows (n=680) and visual surveys of large plastic debris (n=891). The data were used to calibrate an ocean circulation and particle-tracking model (HYCOM/NCODA, Cummings 2005) which was then used to estimate budgets of floating macro and microplastics. Using the validated model, it was estimated that the total number of floating plastic pieces, in the four size categories, was 5.25 trillion (5.25×10^{12}), with a mass of 268,940 tonnes (Figure 27).

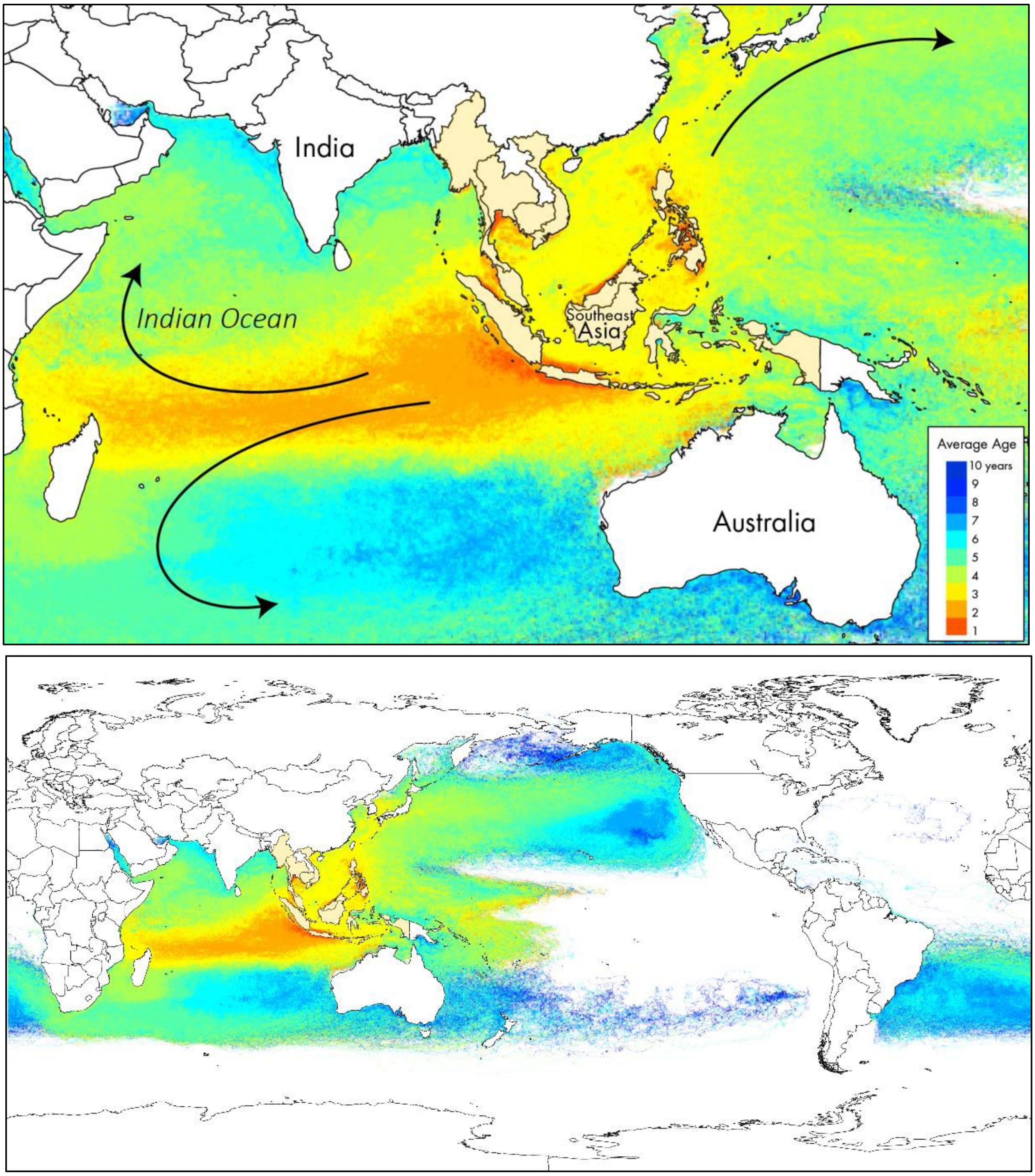


Figure25. Simulation of the transport of particles originating in SE Asia, showing the relative age of particles (1994-2014) in the Indian and Pacific Oceans (top) and globally (bottom). Red indicates 1 year and dark blue 10 years from release (from UNEP 2016).

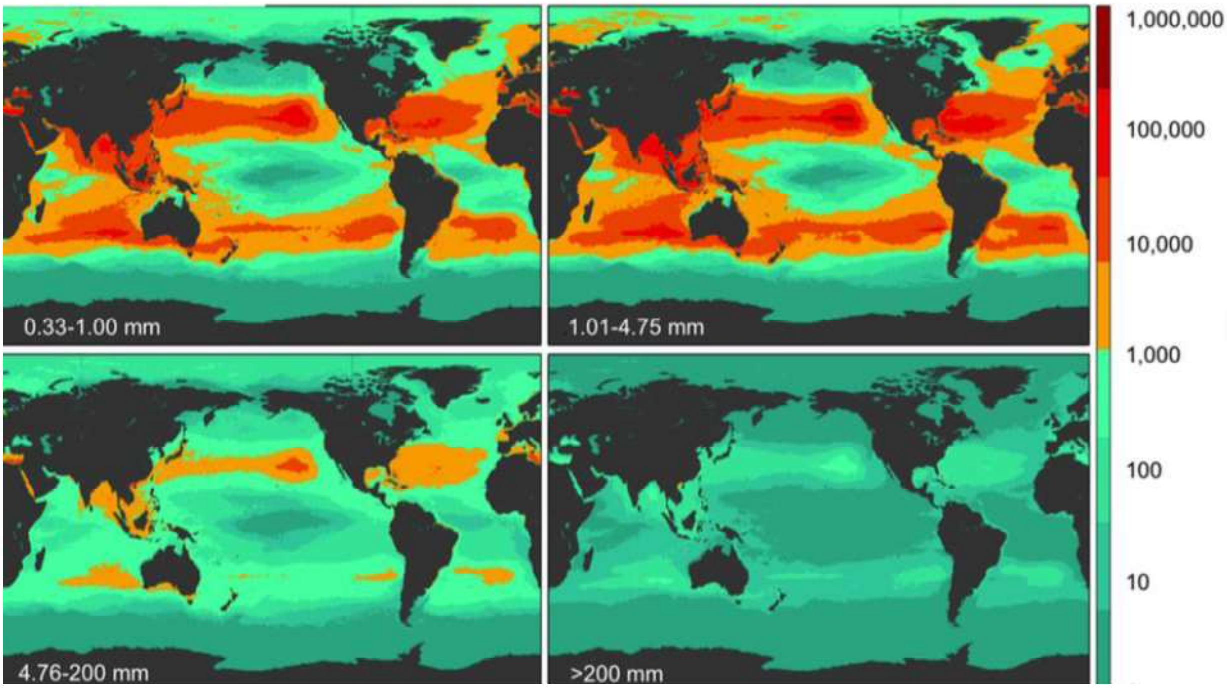


Figure26.Model prediction of the distribution by global count (pieces km-2, see colour scale bar) of particles/items for each of four size classes: 0.33 – 1.00 mm, 1.01 – 4.75 mm, 4.75 – 200 mm, and >200 mm (Eriksen et al. 2014).

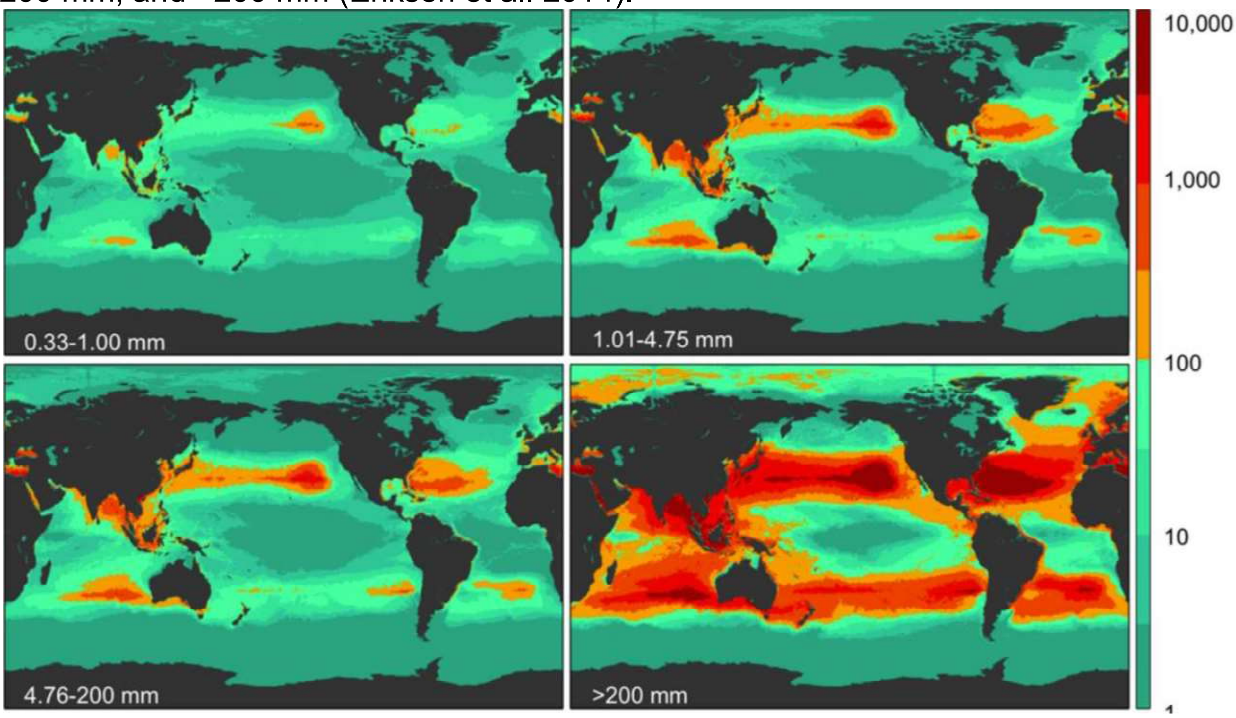


Figure 27. Model prediction of the distribution by weight density (g kg-1, see colour scale bar) of particles/items for each of four size classes: 0.33 – 1.00 mm, 1.01 – 4.75 mm, 4.75 – 200 mm, and >200 mm (Eriksen et al. 2014).

3.3 Sea based sectors generation (micro and macro)

Maritime activities utilize a wide variety of different types of plastics, both those intended for short-term use (e.g. packaging) and longer-term use (e.g. fishing gear, ropes). The principal sources and entry routes are illustrated in Figure 28, and the types of material are further described in Table 3.

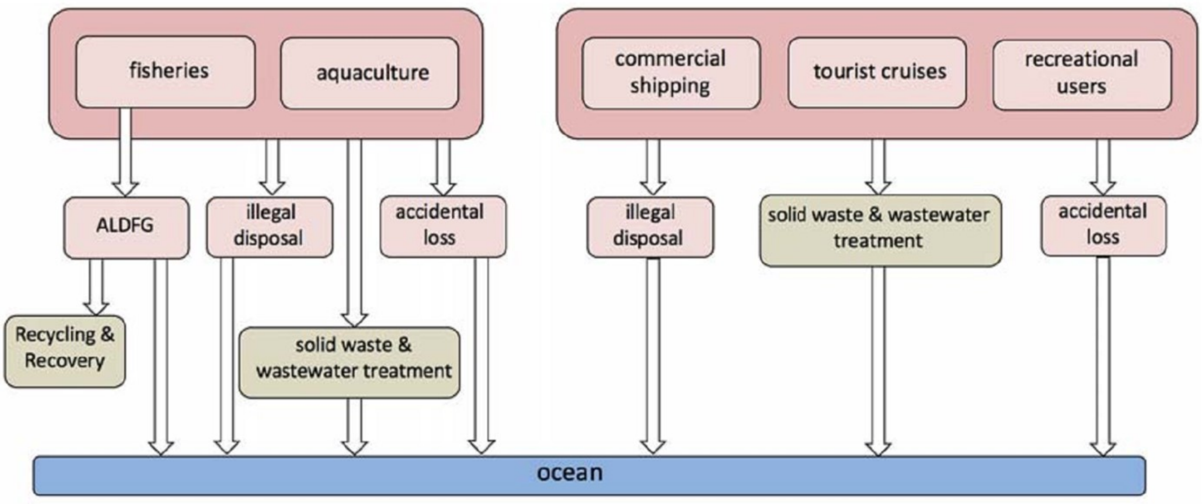


Figure 28. Sea-based sources of macroplastics and pathways to the ocean (Source:UNEP, 2016)

Table 3. Sources of macroplastics by maritime sector (Source:UNEP, 2016)

Source	Description	Entry points	Relative importance
Fisheries	Fishing gear, strapping bands, storage boxes, packaging, personal goods	Coastal, marine	High
Aquaculture	Buoys, lines, nets, structures, storage boxes, packaging, personal goods	Coastal, marine	Medium
Shipping/Offshore industry	Cargo, packaging, personal goods	Coastal, marine	Medium
Ship-based tourism	Packaging, personal goods	Coastal, marine	Medium

Sources such as fisheries or aquaculture may use particular types or quantities of plastics more than other sectors, but a cruise ship, carrying several thousand passengers more represents a medium-sized floating community or town, with a similar scale of demands for goods and services and potential to generate waste.

3.4. National, sub-national and local institutions responsible for solid waste management

National institutions

- Ministry of Environment and Forests
- Ministry of Earth Sciences
- Ministry of Agriculture
- Ministry of Water Resources
- Ministry of Defence (Indian Coast Guard)
- Ministry of Surface Transport
- Ministry of Petroleum and Natural Gas
- Ministry of Tourism
- Ministry of Mines
- National Solid Waste Association of India, Mumbai
- Central Pollution Control Board (CPCB), New Delhi
- National Engineering and Environmental Research Institute (NEERI), Nagpur
- Central Institute of Plastics Engineering and Technology (CIPET), Chennai
- Centre for Environmental Science & Engineering, IIT- Bombay, Mumbai
- TERI (The Energy and Resources Institute), New Delhi
- Environmental and Water Resources Engineering Division, IIT-Madras, Chennai
- Centre for Rural Development and Technology, IIT Delhi

Sub-national and local companies

- SELCO International Limited, Hyderabad
- Zanders Engineers Limited, Mohali, Punjab
- Ramky Enviro Engineers Ltd., Hyderabad
- Jindal ITF Urban Infrastructure Ltd, Delhi
- Mailhem Engineers Pvt. Ltd., Pune
- Southern Cogen Systems Pvt Ltd, Mysore, Karnataka

4. NATIONAL IMPACT OF MARINE LITTER

4.1 Social

Human health and food safety

Plastic pollution is the most widespread problem affecting the marine environment. It also threatens ocean health, food safety and quality, human health, coastal tourism, and contributes to climate change. Invisible plastic has been identified in tap water, beer, salt and are present in all samples collected in the world's oceans, including the Arctic. Several chemicals used in the production of plastic materials are known to be carcinogenic and to interfere with the body's endocrine system, causing developmental, reproductive, neurological, and immune disorders in both humans and wildlife.

Toxic contaminants also accumulate on the surface of plastic materials as a result of prolonged exposure to seawater. When marine organisms ingest plastic debris, these contaminants enter their digestive systems, and overtime accumulate in the food web. The transfer of contaminants between marine species and humans through consumption of seafood has been identified as a health hazard, but has not yet been adequately researched (Bergmann et al., 2015).

Loss of intrinsic value and the moral dimension

The loss of intrinsic value encompasses our response to being aware of a degradation of the environment, whether this is litter on a deserted shoreline or images of injured or dead iconic species, such as turtles, birds and marine mammals. It is very difficult to quantify the impact reliably, except in the case where a change in behaviour apparently linked to the degree of degradation be observed, as in the tourism examples above. It can be surmised that the closer the relationship individuals feel to the example of litter-induced degradation then the greater will be the sense of loss. This may undermine some of the benefits associated with coastal and marine environments (UNEP, 2016).

Human and animal health

The most visible and disturbing impacts of marine plastics are the ingestion, suffocation and entanglement of hundreds of marine species. Marine wildlife such as seabirds, whales, fishes and turtles, mistake plastic waste for prey, and most die of starvation as their stomachs are filled with plastic debris. They also suffer from lacerations, infections, reduced ability to swim, and internal injuries. Floating plastics also contribute to the spread of invasive marine organisms and bacteria, which disrupt ecosystems.

The recent studies showed the effects of plastic ingestion on the bioaccumulation of organic chemicals, emphasizing quantitative approaches and mechanistic models (Koelmans, 2015). It appears that the role of microplastics can be understood from chemical partitioning to microplastics and subsequent bioaccumulation by biota, with microplastic as a component of the organisms' diet.

Microplastic ingestion may either clean or contaminate the organism, depending on the chemical fugacity gradient between ingested plastic and organism tissue. To date, most laboratory studies used clean test organisms exposed to contaminated microplastic, thus favouring chemical transfer to the organism. Observed effects on bioaccumulation were either insignificant or less than a factor of two to three. In the field, where contaminants are present already, gradients can be expected to be smaller or even opposite, leading to cleaning by plastic. Furthermore, the directions of the gradients may be opposite for the different chemicals present in the chemical mixtures in microplastics and in the environment. This implies a continuous trade-off between slightly increased contamination and cleaning upon ingestion of microplastic, a trade-off that probably attenuates the overall hazard of microplastic ingestion.Bioaccumulation can be modelled using traditional approaches that use a mass balance of uptake and loss processes (Figure 29).

Given that most currently used plastic polymers are highly resistant to degradation, this influx of persistent, complex materials is a risk to human and environmental health. Continuous daily interaction with plastic items allows oral, dermal and inhalation exposure to chemical components, leading to the widespread presence in the human body of chemicals associated with plastics.

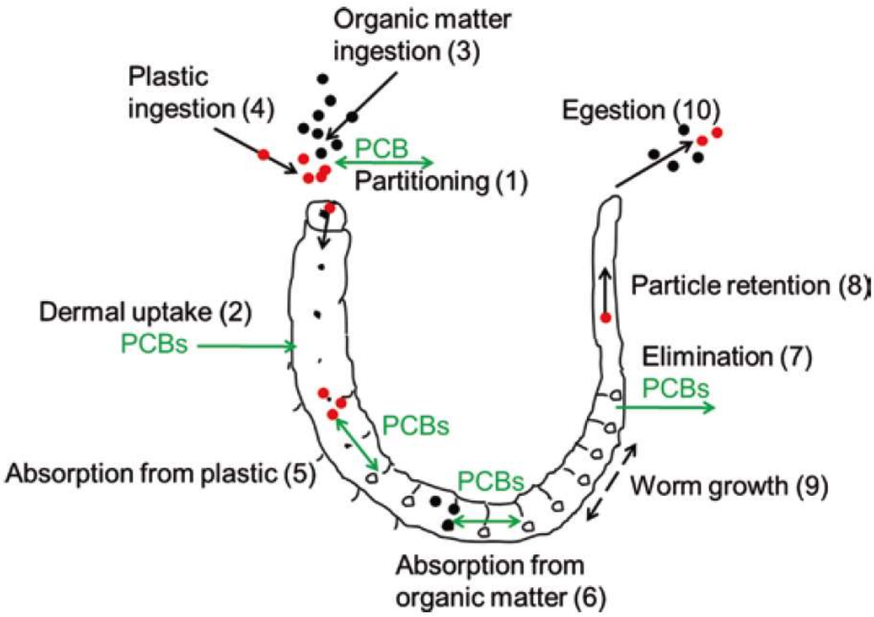


Figure 29. Schematic representation of processes required for plastic-inclusive bioaccumulation modeling (example for PCBs accumulation in a lugworm Arenicola marina): 1 Partitioning between plastic, sediment and water, 2 dermal uptake, 3 organic matter (food, biofilm)ingestion, 4 microplastic ingestion, 5 absorption from plastic, 6 absorption from organic matter, 7 elimination, 8 particle retention, 9 worm growth, 10 particle egestion (sediment and plastic). Same or similar process descriptions can be used for other marine/aquatic organisms(Source:Koelmans et al., 2013).

Indiscriminate disposal places a huge burden on waste management systems, allowing plastic wastes to infiltrate ecosystems, with the potential to contaminate the food chain. Of particular concern has been the reported presence of microscopic plastic debris, or microplastics (debris ≤1 mm in size), in aquatic, terrestrial and marine habitats. Yet, the potential for microplastics and nanoplastics of environmental origin to cause harm to human health remains understudied.

In terms of human health risks, microplastics as contaminants in the wider environment represent a concern because it has been shown that they can be ingested by a wide range of aquatic organisms, both marine and freshwater, and thus have the potential to accumulate through the food chain. Aquatic organisms for which ingestion of microplastics has been documented in the field include those from across the marine food web, including turtles, seabirds, fish, crustaceans and worms. The majority of studies have documented microplastics in the guts of organisms, an organ that is not generally consumed directly by humans.

Garrettet al. (2012)used a novel bio-imaging technique, multimodal nonlinear optical microscopy, to document uptake of polymeric nanoparticles by enterocytes in the mouse gut in vivo. They studied a novel amphipathic polymer specifically designed for drug delivery, ammonium palmitoyl glycol chitosan (GCPQ) of 30–50 nm in diameter and showed that after uptake by enterocytes, particles accumulated at the base of the villi. From there, they passed into the blood stream and were transported to the liver, where they were detectable in the hepatocytes and intracellular spaces, before recirculating through the bile to the small intestine (Garrett et al. 2012) to be excreted with faecal matter. This is similar to previous results for larger micron-scale polystyrene and latex particles, suggesting that both micron and nano-scale polymers are treated in a similar manner (Jani et al. 1996), with uptake across the gut, recirculation and eventual elimination through faecal matter and urine (Figure 30). This information is of high interest in terms of drug delivery, yet it also suggests that ample opportunity exists, following ingestion, for micro- and nanoplastics in food or water to enter, circulate and bioaccumulate within the body.

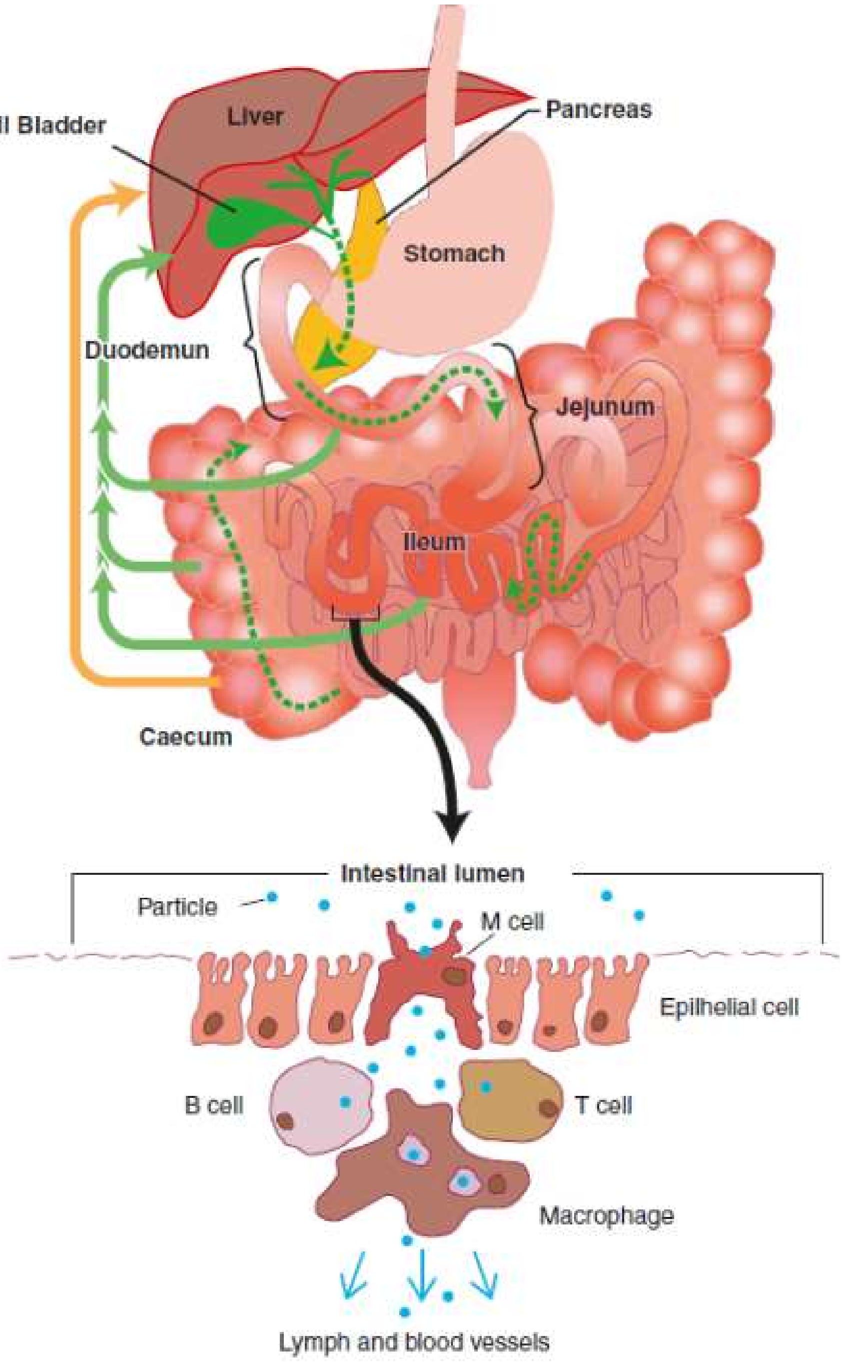


Figure 30. A diagram illustrating a proposed recirculation pathway for polymer nanoparticles (ammonium palmitoyl glycol chitosan) after oral administration. The nanoparticles are taken up into the blood from the gut through M cells, and from there through the lymphatic system (shown in yellow) and into the liver and gall bladder. Particles are then re-released into the gut together with bile (shown in green) before excretion in faeces and urine.Adapted from Garrett et al. (2012).

4.2 Economic

From ecosystem impacts to economic consequences

Measuring the full economic cost of marine litter is complex due to the wide range of economic, social and environmental impacts, the range of sectors impacted by marine litter and the geographic spread of those affected. Some of the impacts are easier to evaluate in economic terms because they are more direct, such as increased marine litter cleaning costs. Others are more complex, for example, the less direct and/or more intangible values such as the impacts of ecosystem deterioration or reductions in quality of life. Furthermore, the spatial and temporal complexity of the impacts related to marine litter result in costs, which may not always be immediate or conspicuous but are nevertheless significant for sustainability (NRC, 2008). As regards ecosystem degradation, it is useful to differentiate between impacts on biodiversity (species and habitats) and the impact on the ecosystem services flowing from the ecosystem (e.g. provisioning services such as food provision, regulating services such as water and waste purification; and cultural services such as tourism and recreation). As regards economic costs it is important to differentiate between actual economic costs linked to expenditure (e.g. costs of cleanup of beaches; costs associated with damage to or loss of fishing gear or obstruction of motors; eventual cost of hospitalisation from marine debris related health impacts), economic costs of loss of output or revenue (e.g. loss of revenue from fish or loss of income from tourism) and assessment of welfare costs in economic terms (e.g. health impacts from marine debris; assessing the economic value of loss of cultural values such as recreation or landscape aesthetics).

While marine litter has become an increasingly important issue in policy discussions, there is only a very sketchy body of knowledge on the costs of the impacts. Because of a lack of recording even the direct economic costs of marine litter tend not to be measured. Furthermore, even though there is a growing interest in ecosystem services (Costanza et al., 1997; TEEB, 2010) little research has been done to date on the economic cost of marine litter on ecosystem service provision. Having said this, evaluations of marine ecosystem services, which are estimated at €16.5 trillion in one study, suggest that even fractional deterioration in provision would represent a significant cost (Beaumont et al., 2007). Thus far, studies undertaken to estimate the economic impacts of marine litter have generally focused on the direct losses borne by economic activities adversely affected by the presence of marine litter in the environment, within which they operate and rely upon (MacFayden 2009; McIlgorm et al. 2011). Largely, such studies have not taken into account the often intangible costs of any social and ecological impacts. Some early studies allude to the need for research to explore these costs. For instance, Kirkley and McConnell (1997) call for strategies, which account for the economics related to lost ecological functions driven by marine litter. The intricacy of developing such strategies can be illustrated with the example of alien invasive species. Marine litter provides additional opportunities for marine organisms to travel (including alien invasive species) up to threefold (Barnes 2002). Given that the introduction of alien invasive species can have a detrimental impact on marine ecosystems and biodiversity (Kiessling et al. 2015) and can result in serious economic losses to many marine industries, any estimates, which exclude such ecological impacts, will inevitably fall seriously short of the true cost of the marine litter problem.

Attempts have been made to develop methodologies for quantifying non-use values (e.g. UNEP 2011), but such analyses are often hindered by the lack of relevant and reliable data. Different forms of contingent valuation may be used (e.g. stated preference, willingness to pay), based on a rather limited number of studies, which are then applied globally, to dissimilar social and economic settings, not taking into account local attitudes and values (UNEP2014). Therefore, such figures as do exist should be treated with some caution if taken out of context. But such analyses do serve to illustrate the likely extent of external costs (Figure 31).

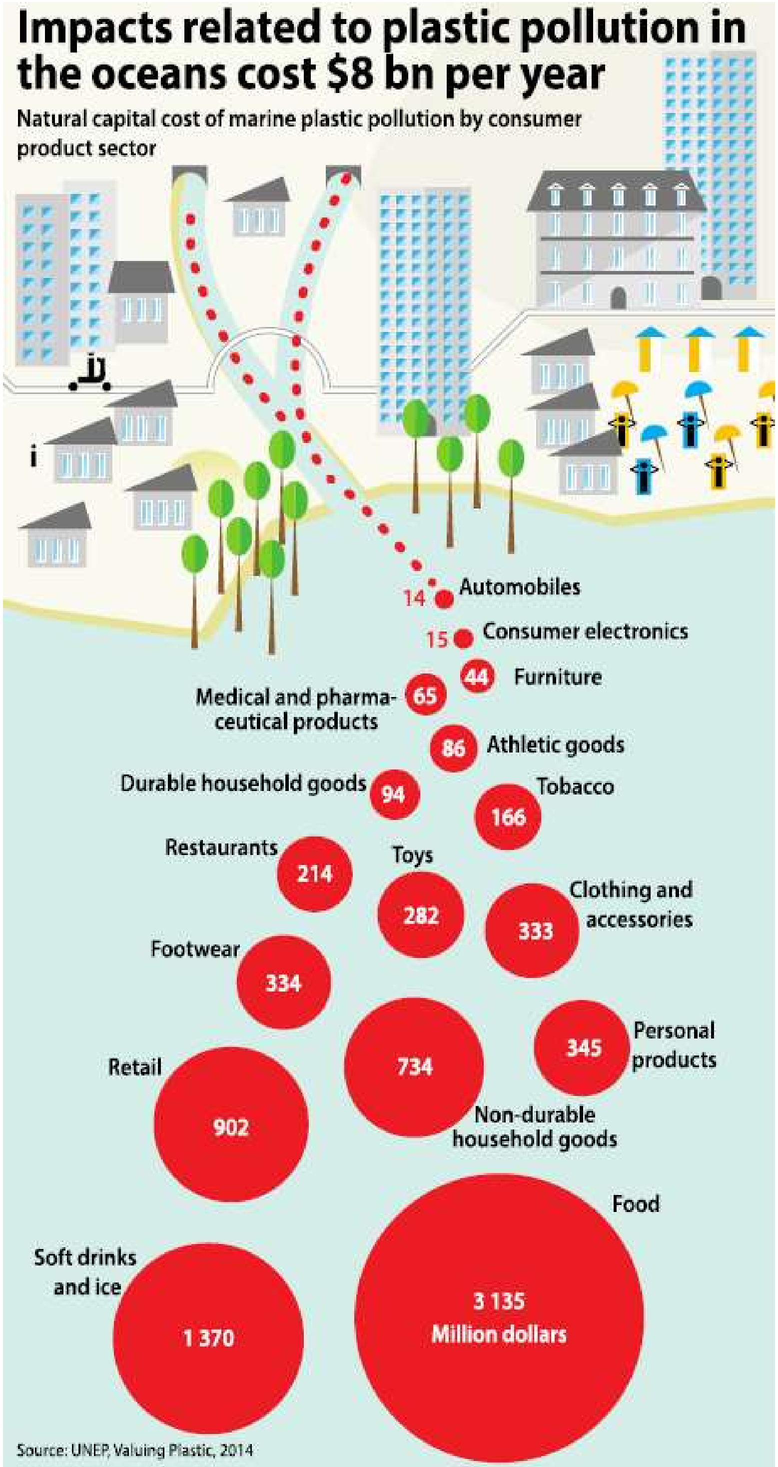


Figure 31. Economic impact of plastic pollution in the ocean (Source: UNEP, 2014).

Plastic products consumption and recycle in India:

The level of plastic consumption India is a tenth of the United States of America (Figure 32). The amount of plastic products exports are also given in Figure 33. Currently in India, number of organized recycling units for plastics is ~3,500 along with additional ~4,000 unorganized recycling units. Most of the plastics (PE, PP, PVC, PET, PS,) etc. could be recycled via mechanical route. Whereas, engineering plastics like PBT, SAN and Nylon etc. are recycled by selected recyclers. In India, recycling of plastics is currently 3.6MnTPA and it provides employment to almost 1.6 Million people (0.6 million directly, 1 million indirectly).The following figure 34 shows the typical plastic recycling method. India recycles about 60% of its plastics, compared to world's average of 22%. Plastic waste contains the calorific value equal to fuel. India has among the lowest per capita consumption of plastics and consequently the plastic waste generation is very low as seen from the Table 4

Figure 32: Per capita plastic products consumption (Kg/person) (Source: FICCI, 2017)

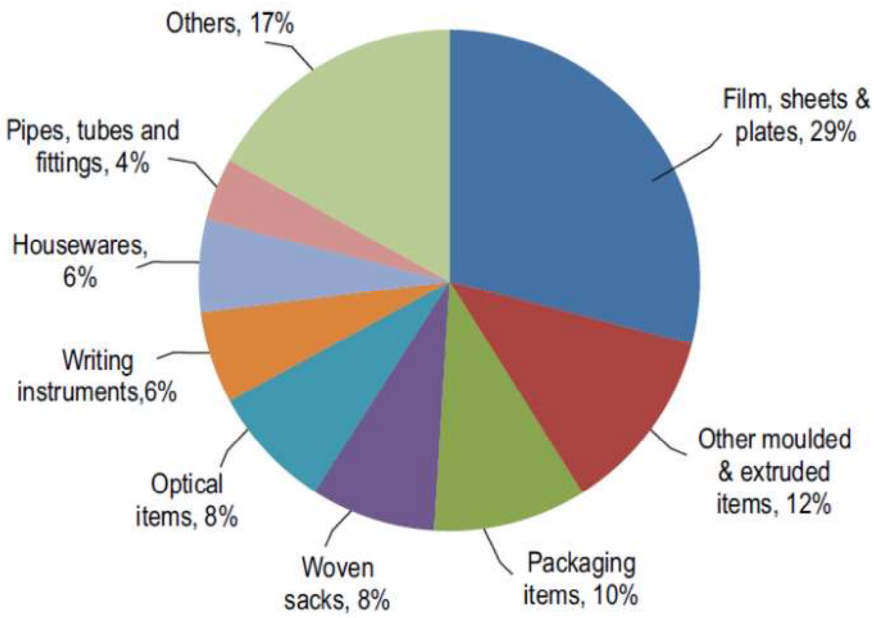


Figure 33: Product wise breakup of plastic product exports in 2012-13 (Source: Plastindia, Analysis by Tata Strategic)

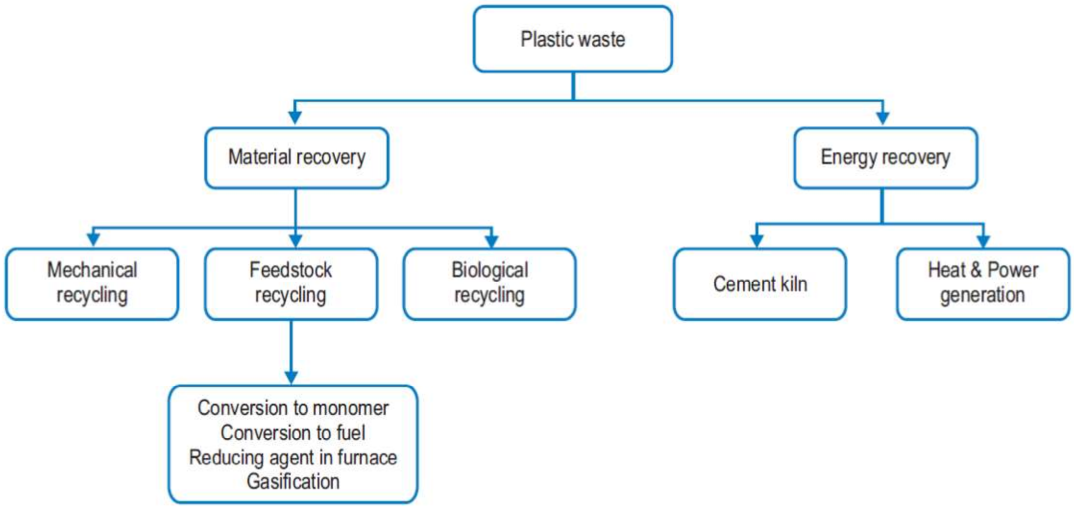


Figure34. Plastic recycling flow diagram

Table 4: Plastic Waste Consumption (Source: Central Pollution Control Board)

S.No.	Description	World	India
1.	Per capita per year consumption of plastic (kg)	24	6-7
2.	Recycling (%)	15-20	60
3.	Plastic in Solid Waste (%)	7	9

Fisheries and aquaculture

The fishing sector is more commonly viewed as a source of marine litter, but it is also subject to economic costs itself. Direct economic impacts faced by the sector arise from the need to repair or replace gear that has been damaged or lost due to encounters with marine litter; repairing vessels with tangled propellers, anchors, rudders, blocked intake pipes, etc.; loss of earnings due to time diverted to deal with marine litter encounters; and loss of earnings from reduced or contaminated catches resulting from marine litter encounters including ghost fishing. There are potentially also costs associated with loss of value of fisheries resources (provisioning services under the ecosystem service nomenclature), whether through reductions in fish and shellfish numbers or reduced value due to impacts on quality of fish and shellfish (e.g. through ingested plastics or contamination with persistent organic pollutants, POPs). The body of literature describing the contamination of commercially exploited fish and shellfish by microplastic ingestion is growing rapidly, as is the literature analysing the consequences of this contamination on the health of individuals and populations (Galloway, 2015; Lusher, 2015; Rochman, 2015). However, as yet there have been no economic assessments to estimate the costs of these impacts.

Derelict fishing gear (DFG) constitutes a considerable portion of marine litter and can result in economic losses for fisheries. DFG includes any equipment, which can catch (shell-)fish, which is lost by fisheries, including trawl nets, gill nets, traps, cages and pots (NRC, 2008). As a result of their functional design, DFG can continue to trap marine life after they have been lost (a phenomenon known as ghost fishing). Increasingly durable materials used in fishing equipment means that it can continue to ghost fish for some time; in this way it presents particular challenges as marine waste. Fisheries incur costs, firstly in having to replace the fishing gear they have lost at sea, and secondly in a reduction in their potential harvestable catch, and indeed the sustainability of that catch.

Marine litter can result in costs to the aquaculture industry, through entangling propellers and blocking intake pipes, and time spent removing debris from and around fish farm operations. Removing marine litter from aquaculture sites was less of an issue overall, but this was highly variable, and in some areas it was a regular problem. These figures demonstrate that in comparison to other sectors such as fisheries, and even agriculture, the direct cost imposed by marine litter on aquaculture is relatively low.

Tourism, recreation, rafting, surfing etc.

Plastic waste damages the aesthetic value of tourist destinations, leading to decreased tourism-related incomes and major economic costs related to the cleaning and maintenance of the sites. Coastal municipalities are impacted economically by marine litter primarily through the direct cost of keeping beaches clear of litter and its wider implications for tourism and recreation. Direct costs include the collection, transportation and disposal of litter, and administrative costs such as contract management. Ensuring that beaches are clean, attractive and safe for visitors is prioritised by municipalities when the economic case for protecting the local economy and tourism industry justifies the costs of removing the litter. In areas where coastlines make a significant contribution to the economy, the costs incurred through marine litter can be substantial.

The shipping and yachting industries also experience economic impacts as a result of marine litter pollution, with harbors and marinas incurring the cost of removing marine litter from their facilities in order to keep them safe and attractive to users, and vessels experiencing interference with propellers, anchors, rudders and blocked intake pipes and valves. On occasion, some of thesevessel encounters pose navigational hazards that require the rescue services to become involved, thereby increasing costs dramatically (Bergmann et al., 2015).

4.3 Ecological /Environment

Impact on marine ecosystem and biodiversity

Entanglement

Certain groups including birds, cetaceans, crustaceans, sharks and turtles fall prey to plastic snares. Larger vertebrates become ensnared in plastic, forming ‘lethal collars’ on sharks, seals and cetaceans. These can wrap around body parts tightening as the animal grows, restricting movement, cutting off blood circulation and inhibiting predator avoidance. As some plastics take 500 years to break down in natural environments, once a ‘snare’ kills its victim and the body decomposes the plastic is free to entangle more individuals resigning them to the same fate. Some mammals actively seek out plastic. Dolphins and

sea-lions are typically known for their playful and inquisitive natures and are often found entangled in plastic debris where play has ended in catastrophe.
'Ghost fishing' has become a term coined for marine vertebrates caught in long lines of discarded netting left to drift in the sea. Unsurprisingly, this has been found to have detrimental effects at all pelagic levels of the marine biota, affecting species diversities on the sediment and at the surface.

Ingestion

Plastic debris is often mistaken for food by a variety of fauna owing to the visual similarity between plastics and food. This can lead to stomach blockages and consequent starvation in larger vertebrates. Styrofoam mistaken for cuttlefish by birds affects 100 pelagic species, blocking their digestive tracts. Plastic ingestion is a particular problem for smaller birds which store the most and seem to be unable to successfully expel it from their guts following ingestion.
One of the most charismatic animals to be affected by plastic debris are sea turtles. Spending the majority of their life at sea, turtles favourite food are jellyfish which they often mistake for plastic bags. These clog their stomachs leading to starvation and death.

Marine Habitat damage (fauna and flora)

Marine organisms are known to ingest microplastic particles (Nerland et al., 2014). Many commercially important marine organisms are known to contain microplastics with several possible routes for exposure; for example via the mouth and thereby the digestive system or via the gills. Ingestion of microplastics is well known and the digestive system is often examined when looking for the presence of microplastics.

Threat to marine fauna from the ingestion of plastic carry bags and other non-biodegradable debris scattered on the ocean surface and at the seafloor is increasing at alarming proportions.Kaladharan et al. (2014) have found ingestion of four thick plastic bags in the stranded adult female Longman's beaked whale near off Sutrapada, Veraval, Gujarat coast (Figure 35).

Figure35. Ingestion of plastic bags found in Longman's beaked whale (Kaladharan et al., 2014)

Microplastics in the benthic invertebrates from the coastal waters of Kochi, Southeastern Arabian Sea:

Recent study examined microplastic particles present in the benthic invertebrates *Sternaspis scutata, Magelona cinta* (deposit feeders) and *Tellina sp*. (suspension feeder) from the surface sediments of off-Kochi, southwest coast of India (Naidu et al., 2018). The microplastic particles and thread-like fibres detected in these organisms were identified to be polystyrene. Examination of the microplastic particle in *Sternaspis scutata* by epi-fluorescent microscopy showed fragmentation marks on the surface suggesting that the microplastic particle was degraded/weathered in nature (Figure 36). The study provides preliminary evidence of the presence of microplastics in benthic fauna from the coastal waters of India. However, further studies are required to understand the sources, distribution, fate and toxicity of the different types of microplastics in benthic invertebrates in order to identify any potential threats to higher trophic level organisms. All the above areas are hot spots as well as rich in biodiversity. Hence, it is required to monitor regularly the marine litter in these regions.

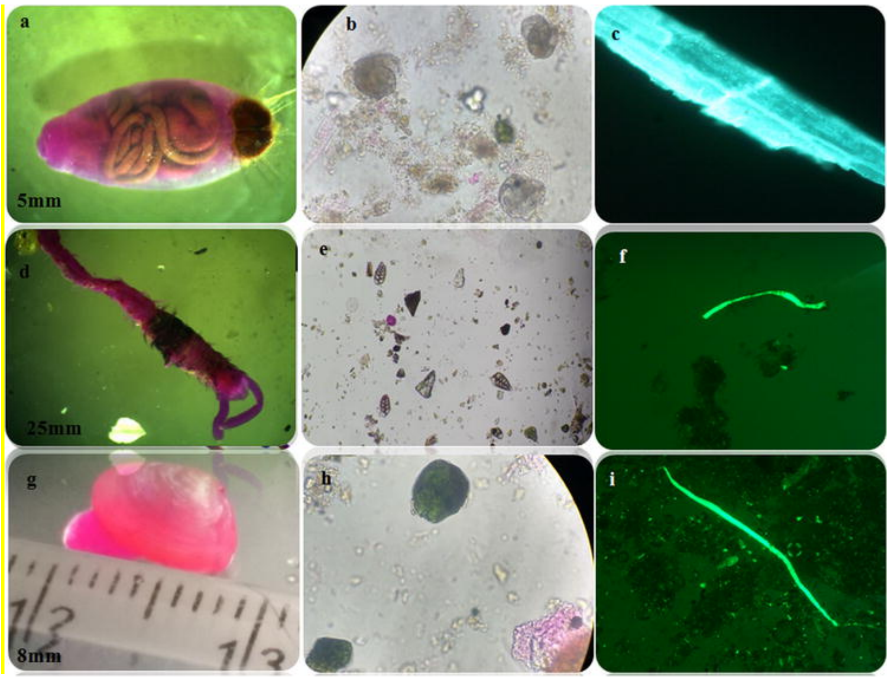
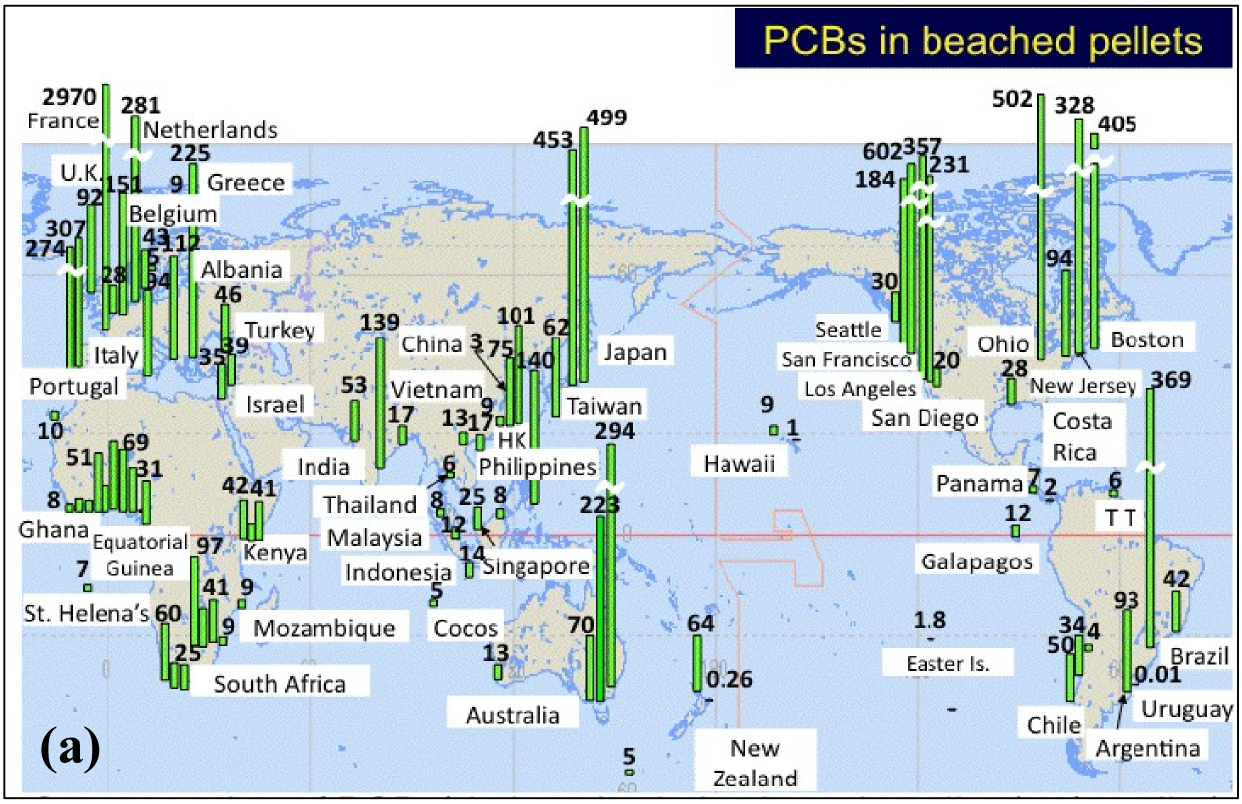


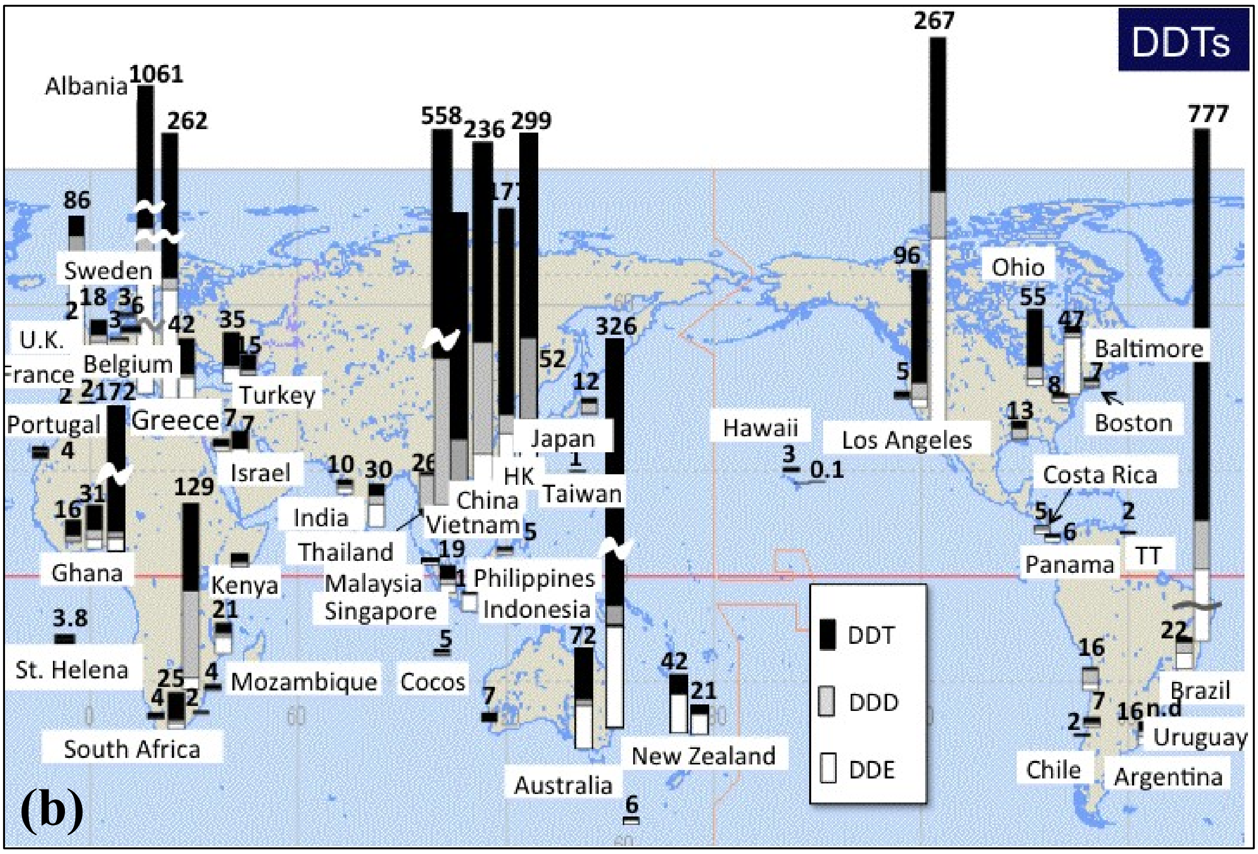
Figure 36. Microplastics in benthic invertebrates from the coastal waters of Kochi, Kerala. (**a** *Sternaspis scutata;* **d** *Magelona cinta;* **g** *Tellina sp.)* and corresponding images representing the gut contents *(**b** Sternaspis scutata; **e** Magelona cinta; **h** Tellina sp.)* and the epifluorescence images of the microplastic particles found in the gut *(**c** Sternaspis scutata; **f** Magelona cinta; **i** Tellina sp.)* (Source: Naidu et al., 2018)

Impacts of ingested material and associated chemicals

In the aquatic environment, the ingestion of plastics also establishes a potential exposure pathway for other chemical contaminants including metals, and persistent, bioaccumulative, and toxic contaminants that may be sorbed from the water column to plastic or incorporated into the plastics during manufacture (Engler, 2012). Given the potential for plastics to be a source of contaminants, from both the chemical constituents of the manufactured plastic itself and contaminants sorbed to plastics in the aquatic environment, there is growing concern about the toxicological impacts of chemicals associated with plastics on aquatic organisms, as well as, aquatic-dependent wildlife, such as seabirds (Teuten et al., 2009). Because plastics have become pervasive in oceans, coasts, and inland watersheds, and there are concerns about the potential toxicological impacts of chemicals associated with plastics on aquatic organisms and aquatic-dependent wildlife, the United States Environmental Protection Agency's (EPA) Office of Water produced a state-of-the-science review that summarizes available scientific information on the effects of chemicals associated with plastic pollution and the potential impact of these chemical on aquatic life and aquatic-dependent wildlife.

International Pellet Watch (IPW) team members have generated the global pollution map based on the concentrations of persistent organic pollutants (PCBs, DDTs, HCHs, Hopanes and PAHs) adsorbed by microplastic resin pellets (Figure37).Plastic also contains additives, chemicals added to improve the desirable properties of the plastic product. Many of these additives are known hazardous substances and can leach from the plastic surface. Plastics once released into the environment can also accumulate known persistent organic pollutants (POPs). Surveys of contaminant in plastic particles collected from beaches suggest that concentrations measured may be representative of the environment these particles were sampled from. Plastic particles have the potential to act as vectors for the transport and release of sorbed contaminants and additives. While transfer of contaminants from ingested plastic particles and debris into organisms has beendemonstrated in laboratory exposures, it is at present uncertain whether contaminated plastic present in the environment can affect contaminant bioaccumulation into marine organisms.

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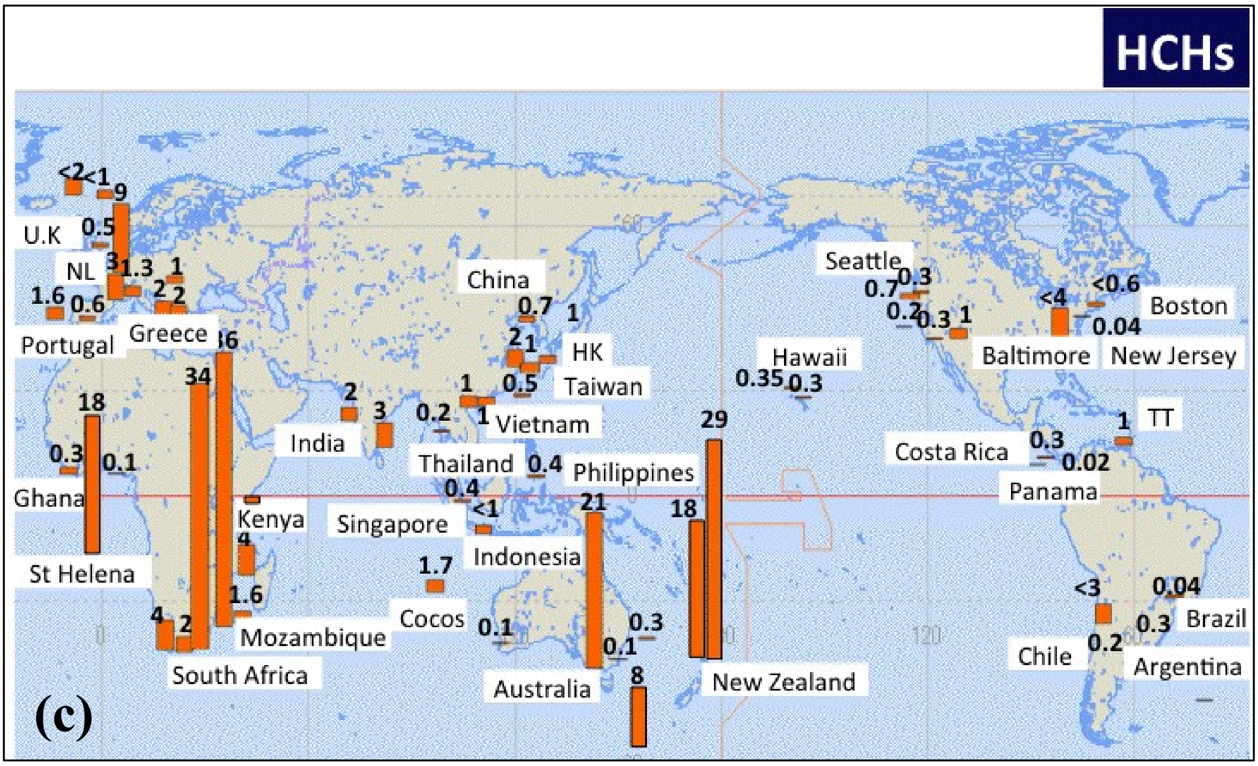
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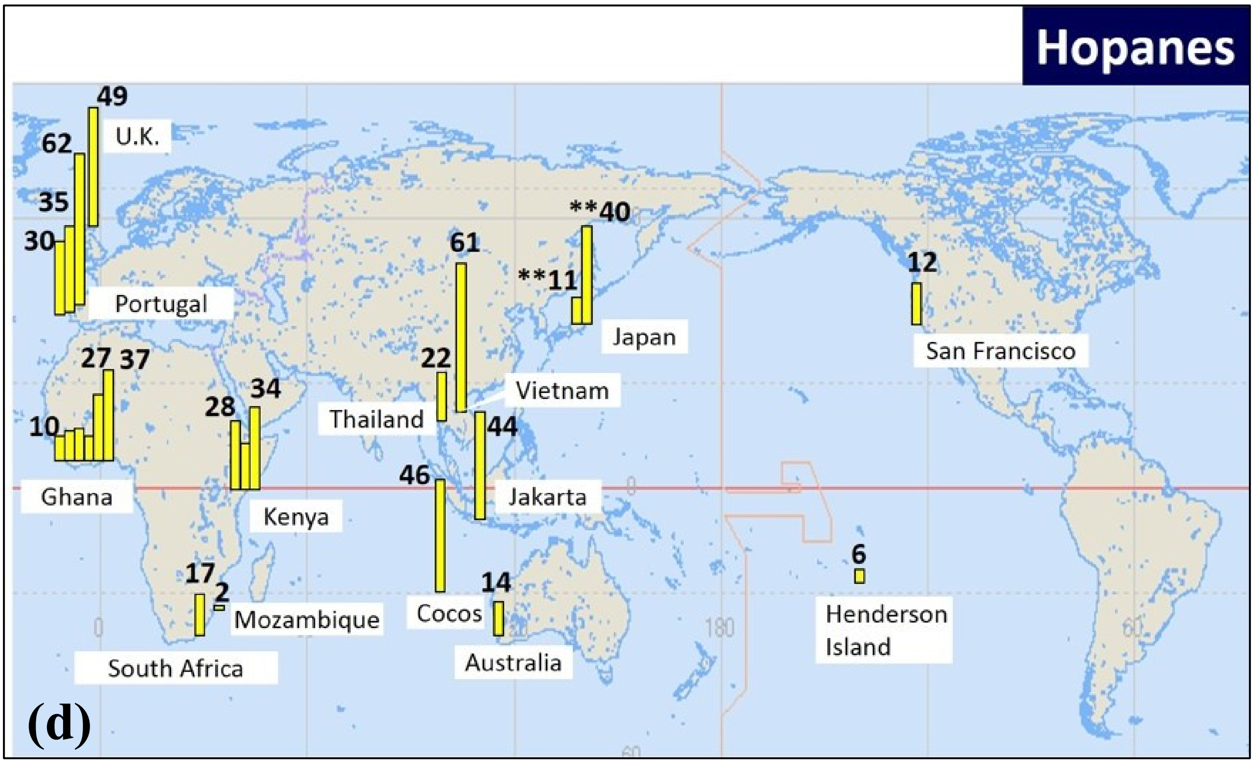

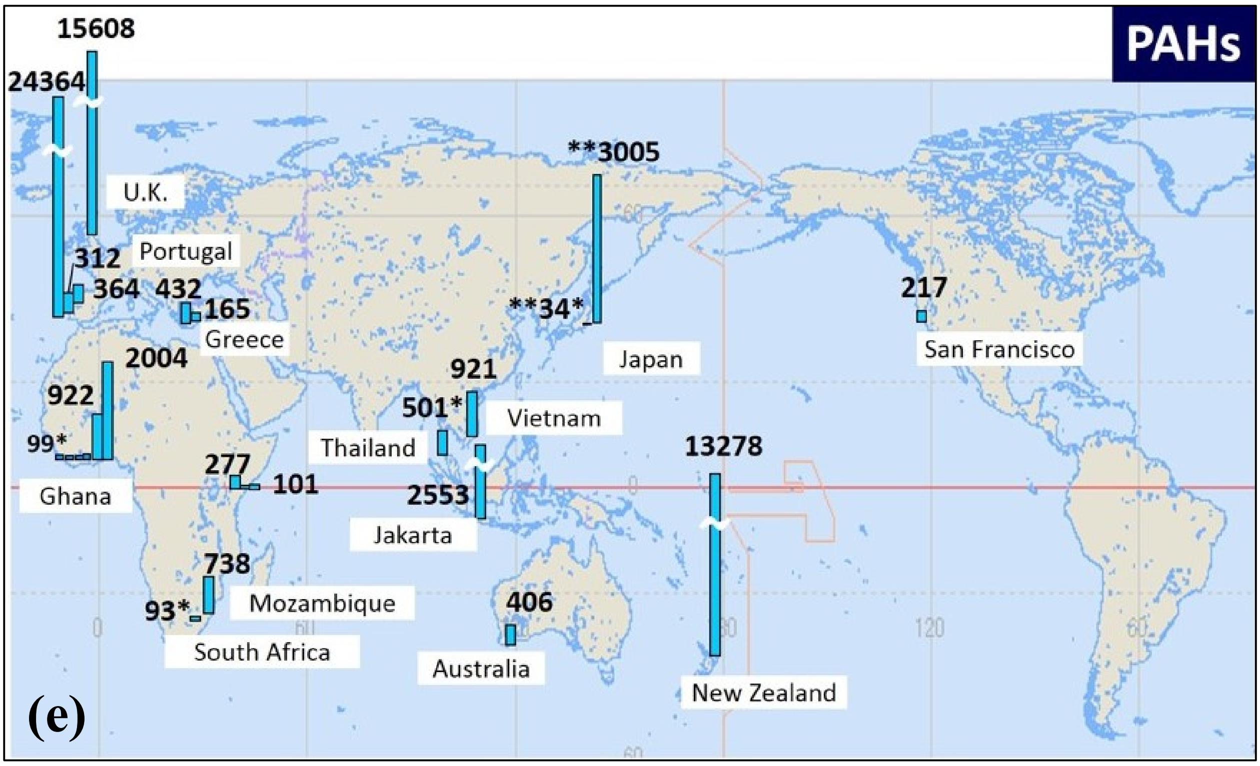

Figure 37. Global distribution of persistent organic pollutants in beached plastic resin pellets ((a) PCBs (ng/g), (b) DDTs (ng/g), (c) HCHs (ng/g), (d) Hopanes (µg/g) and (e) PAHs (µg/g) in beached plastic resin pellet (Source: International Pellet Watch)

5. MANAGEMENT AGENCIES, POLICIES, STRATEGIES AND ACTIVITIES TAKEN TO MINIMIZE THE MARINE LITTER

5.1 Management agencies and their responsibilities

For waste management in India, administration and regulation is governed by the Ministry of Environment and Forests and Climate Change (MoEF), the Ministry of Urban Development (MoUD), the National Environmental Engineering Research Institute (NEERI), CPCB, and State Pollution Control Boards (SPCBs) and ground level implementation responsibility lies with urban local bodies. The state-wise waste generation is given in Annexure – I.

5.2 Management policies and Strategies and their effectiveness

As India does not have National Marine Litter policy, it is the right time to have the same. However, there are legal framework and several waste management programs as detailed in Table 5.

Table5. India's Waste Management Initiatives (India Infrastructure report, 2009)

Policy and Regulation	
Institutional Framework	• Central Level • State Level • Other Organizations/ Associations
Legal Framework	• 74th Constitutional Amendment Act, 1992 • Management and Handling Rules • Environment (Protection) Act, 1986 • National Environment Tribunal Act, 1995 • National Environment Appellate Authority Act, 1997 • Water (Prevention & Control of Pollution) Act, 1974 • Water (Prevention & Control of Pollution) Cess Act, 1977
Environmental Norms	• Existing Environmental Standards • Recently Notified Environmental Standards
Policy Initiatives	• National Urban Sanitation Policy, 2008 • National Environment Policy, 2006 • Policy Statement for Abatement of Pollution, 1992 • National Conservation Strategy and Policy

	Statement on Environment and Development, 1992 • Law Commission Recommendation • Ecomark Scheme, 1991
Key Government Programmes	
JNNURM	• Programme Scope and Structure • Funding • Experience so far • Experience on Reforms • Issues and Challenges
Total Sanitation Campaign	• Programme Scope and Structure • Funding • Experience so far • Experience on Reforms • Issues and Challenges
MNRE's Waste-to-Energy Programmes	• Programme Scope and Structure • Experience so far • Experience on Reforms • Issues and Challenges
Other Programmes	• Integrated Low Cost Sanitation Scheme • National Biogas and Manure Management Programme
Technology and Practices	
Traditional Technologies	• Landfills • Waste Incineration • Sanitation
Key Projects	• Kolkatta: SWM Improvement Project • Kanchrapara: SWM through Citizens' Participation • Kollam: MSW Management Project • Chennai: MSW Project • Navi Mumbai: MSW Management Project • Gurgaon: Ultra-Modern Waste Management Plant • Namakkal: Zero Garbage Status • Suryapet: Dustbin Free and Zero Garbage Town • Visakhapatnam: SWM Though Citizens Participation • Thiruvananthapuram: Decentralised SWM • CIDCO: SWM System at Areas Adjoining Navi Mumbai
Key Initiatives	• Chennai: GPRS Equipped Waste Bin • Ahmedabad: Tapping Methane Gas • Goa: Solid Waste Management Corporation • Nagpur: Bye-Laws to Collect Waste Generated

	in Hotels • Nagpur: Management of Construction Debris • Akola: CBO for Waste Management • Yavatmal: Door-to-Door Collection of Solid Waste
Rural Waste Management	
Key Projects	• Tamil Nadu: Zero Waste Mgt. at Vellore District • Maharashtra: Slwm at Dhamner Village • Gujarat: Greywater Mgt. at Wadgaon Village • Nashik: Wastepaper to Pepwood • Kerala: Post-NGP Initiatives at Kattapana Village
Industrial Solid Waste Mgt.	
Key Projects	• Andhra Pradesh: 3.66-MW Power Generation Project • Uttar Pradesh: 6-MW Biomass Cogeneration Power Plant • Other WTE Projects • Kolkatta: Waste Minimization of Small-Scale Industrial Units • Himachal Pradesh: Waste Treatment Plant
Liquid Waste Management	
Key projects	• Municipal Liquid Waste • Other Noteworthy Water Reuse and Recycling Projects • Industrial Liquid Waste

5.3 Management activities done for Land base, Beach base and marine base litter

The following are major steps taken by GOI for solid-waste management in India during last two and half decades:

- National waste management committee: The main objective of the committee constituted in 1990 was to identify the recyclable contents in solid waste picked up by rag-pickers.
- Strategy Paper: A manual on SWM has been developed by the MoUD in collaboration with the NEERI in August, 1995.
- Policy Paper: MoUD and the Central Public Health and Environmental Engineering Institute prepared a strategy paper for the treatment of wastewater, appropriate hygiene, SWM, and efficacy in drainage system.

- Master plan of Municipal Solid Waste: A stratagem was formulated by the combined efforts of MoEF, CPCB, and ULBs to develop a master plan for SWM with emphasis to biomedical waste in March, 1995.
- High Powered Committee: In 1995, a High Powered Committee constituted under the Chairmanship of Dr. Bajaj, to encompass a long-term strategy for the SWM using appropriate technology.

All the above efforts, culminated into preparation of many acts and regulations to protect the environment, which came into force time to time. The rules relevant to SWM in India are as follows:

Hazardous Waste (Management, Handling and Transboundary movement) Rules (1989, amended January 2003, August 2010): It is to control, manage and handling of hazardous waste.

Biomedical Waste (Management and Handling) Rules (1998): It is related to control, manage, and handling of waste generated from hospital, super speciality centers, and nursing homes. Municipal Solid Waste (Management and Handling) Rules, 2000: These rules are applicable for MSW and be implemented by ULBs for scientific management. The Batteries (Management and Handling) Rules (2001): It is applicable to stake holders associated with the manufacturing, handling, and utilization and reuse of batteries or components thereof. Plastic Waste (Management and Handling) Rules, 2009: It deals with scientific disposal of plastic waste and extended producer responsibility clause has also been incorporate in it. E-Waste Management and Handling Rules 2011: It is applicable to stake holders associated with the manufacturing, handling, utilizing, processing, and recycling electrical and electronic-related waste items.

Most researchers emphasize that urban local bodies (ULBs) fails to implement these laws adequately. However, needs and aspirations of stake holders demands for appropriate municipal solid waste management and accordingly the GOI is continuously encourages ULBs to implement these rules at ground level and recently draft notification for municipal solid waste (Management and Handling rules 2015) is also under formulation (Ministry of Environment, Forest and Climate Change, 2015).

6. NATIONAL MARINE LITTER MONITORING PROGRAMME

6.1 Monitoring

Towards ongoing efforts of the Indian Government for the 'Clean India' (Swachh Bharat Abhiyan) and Hon'ble Prime Minister's appeal for mass cleanliness and sanitation campaign through "Swachhta Hi Seva"; the Indian Coast Guard conducted International Coastal Cleanup day-2017 (ICC-2017) in all Coastal States /Union Territories on 16 Sep 2017 along with SACEP, UNEP, SAS, NGOs, NCC cadets, NSS, School and college students, Industries and citizens.The nationwide campaign resulted in the collection of approx 81,335 Kgs of marine litter. Debris collection was highest in Tamil Nadu with approx 15,400 kgs and in Maharashtra was approx 13,300 kgs (Table 6).

Table 6: State wise participation and debris collection (Source: Indian Coastal Guard, Ministry of Defence)

Sl	State/UT	No. of Participants	Debris collected (Kg)
1	Delhi	650	1000
2	Gujarat	1971	11630
3	Daman	700	12000
4	Maharashtra	6320	13300
5	Goa	880	1350
6	Karnataka	5000	10500
7	Kerala	430	460
8	L&M Islands	719	1950
9	Puducherry	1292	2545
10	Tamil Nadu	2840	15400
11	Andhra Pradesh	1000	4000
12	Odisha	466	165
13	West Bengal	753	1405
14	A & N Islands	1581	5630
	Total	**25602**	**81335**

There may be separate parallel decentralized schemes by the government. Financial support by the community based on decentralized schemes will provide the right impetus for the development of waste management method. For example the municipality of Bangalore has a parallel scheme, “Swaccha Bangalore”, which levies mandatory fees for all households, businesses and educational institutions to increase its financial resources. These user fees imply that the residents will expect the municipality to provide proper waste collection services. It integrates them into the overall waste management strategy in all localities thereby helping to reduce the amount of wastes going outside the locality.

General public can play a very important role. Public participation is necessary for a proper waste management system. Changes in the habits of segregation, littering, can change the approach towards wastes. For example in a heritage town of West Bengal, there was a movement related to waste management. Within a span of two years it successfully sensitized residents for segregation at source and not littering in open areas. Now the city is really becoming clean and other people are also participating in the movement. In order to improve the system efficiency and increase the coverage to 100 percent in each city, it is recommended to explore alternative arrangements for collection of waste like involving private operators. A mechanism to generate revenue from the citizens should also be developed. However, the approach to public-private partnerships pursued in the developed countries cannot be replicated for Indian towns in general. This approach can only be implemented after some modifications taking into account the local conditions.

6.2 Base line and targets in the context of monitoring marine litter in the sea

States and Union territories are required to prepare action plans for cities and towns based on the population and waste generation. Steps/action need to be taken could be indicated in a phased manner. The cities generating waste between 100 - 200 TPD and 200 - 1000 TPD for indication /illustration are given in Annexure II and III.

7. KNOWLEDGE GAPS, RESEARCH AND ANALYSIS FOR SETTING PRIORITIES

Over the past decade, increased scientific interest has produced an expanding knowledge base for marine litter especially microplastics, nevertheless, fundamental questions and issues remain unresolved. An evolving suite of sampling techniques has revealed that microplastics are ubiquitous and widespread marine litter, present throughout the water column. However, disparity in the size definitions of microplastics and lack of comparability of microplastic sampling methodologies hinder our ability to cross-examine quantitative studies to better determine spatial and temporal patterns of this contaminant.

Some of the major knowledge gaps for combating marine litter and microplastics are as follows:

- ✓ Paucity of information and quantitative data on the sources and extent of marine litter.
- ✓ No proper environmentally sound management of land based municipal solid waste.
- ✓ Lack of adequate knowledge amongst public on the deleterious effects of the marine litter on the health and economy.
- ✓ Non-availability of efficient waste treatment technology and facilities.
- ✓ Lack of proper coordination among the responsible institutions, stake holders, and provision of adequate financing for recycling of wastes.
- ✓ Social and economic disparity, traditions, cultural beliefs and customs

India’s present Initiatives and Recommendations:

Under the aegis of the Swachh Bharat Abhiyan (Clean India Mission) campaign, Government of India is working enthusiastically on various aspects of pollution. Since 1990s, coastal locations near major settlements and industries are being monitored for various water, sediment and biological parameters of ecological relevance. The activities on the monitoring of marine litter and micro-plastics are meagre and have been initiated recently along the Indian coastline and coastal waters to have a scientific understanding on the type, source, process and distribution of marine litter that would be supportive to frame a "Marine Litter Policy" for India.

To start with, Government of India has already initiated a program i.e., phasing out single use plastic shopping bags and promoting the usage of cotton/jute cloth bag. Beach cleaning is an effective way to reduce and prevent litter from being washed into the seas. As part of the clean coast program, beach cleaning activities, educating school kids, raising awareness among public are being actively pursued. India being a member country of the UNEP, and South Asia Cooperative Environment Program (SACEP) is responsible for clean seas of South Asia Seas (SAS). In this regard, our efforts are being directed towards transforming from the traditional waste management practices to more sustainable waste management practices following 3R- Reduce, Reuse and Recycle concept. To this effect, a country current status report on marine litter has been prepared and discussed at the 8th Regional 3R forum in Asia and Pacific on 10 April, 2018 organised by UNCRD at Indore, India. As a future recommendation as India does not have a National Marine Litter policy, it is the right time to frame a policy that can take care of controlling the litter at the land boundary itself, as it is very difficult to remove the litter once it goes into marine environment.

8. WAY FORWARD

India is well aware that developing a litter free clean and sustainable marine environment requires considerable research efforts towards understanding the fundamental research gaps relating to litter quantities and their impacts on the marine environment. Efforts are to be made in defining priorities, improving the scientific and technical basis of monitoring and modelling methodologies before developing necessary legislation to combat the problem of marine litter.

In order to initiate the process the following immediate priorities are identified by the Ministry of Earth Sciences and would be carried out as part of the existing programmes of the Ministry.

- Understand the source, transport and destination regions of marine litter around the country (pilot studies) using hydrodynamic models
- Evaluation of the behaviour , rate of degradation and factors affecting the fate of litter
- Study the environmental impacts of marine litter on organisms
- Standardization of monitoring protocols for marine litter for the SAS regions.

9. CONCLUSION

To combat marine litter issues institutional strengthening, capacity building, public awareness and a continuous review of the monitoring, innovation and improvement of the activities needs to be addressed in a timely manner. Strategic planning and development of integrated waste management plans at local, city, regional and national level. Community participation, collaboration with industries, non-governmental organisations and other development partners is a key to ensure the successful implementation of the different response options.

10. ACKNOWLEDGEMENTS

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Annexure I: STATE-WISE GENERATION, COLLECTION AND TREATMENT

(data of Annual Report 2013-14 & 2014-15)

S.No	States	Generated (TPD)	Collected (TPD)	Treated (TPD)	Landfilled (TPD)
1	Andaman & Nicobar*	70	70	05	
2	Andhra Pradesh*	4760	4287	6402	
3	Arunachal Pradesh	116	70.5	0	
4	Assam	650	350	0	
5	Bihar	1670	-	-	
6	Chandigarh	370	360	250	
7	Chhattisgarh*	1896	1704	168	
8	Daman Diu & Dadra*	85	85	Nil	
9	Delhi	8370	8300	3240	
10	Goa	450	400	182	
11	Gujarat	9988	9882	2644	
12	Haryana	3103	3103	188	
13	Himachal Pradesh	276	207	125	150
14	Jammu & Kashmir*	1792	1322	320	375
15	Jharkhand*	3570	3570	65	
16	Karnataka	8697	7288	3000	
17	Kerala	1339	655	390	
18	Lakshadweep*	21	-	-	
19	Madhya Pradesh	6678	4351	-	
20	Maharashtra	22,570	22,570	5,927	
21	Manipur*	176	125	-	
22	Meghalaya	208	175	55	122
23	Mizoram*	552	276	Nil	
24	Nagaland	344	193	-	
25	Orissa	2374	2167	30	
26	Puducherry	495	485	Nil	
27	Punjab*	4105	3853	350	
28	Rajasthan*	5037	2491	490	
29	Sikkim*	49	49	0.3	
30	Tamil Nadu	14500	14234	1607	
31	Tripura	415	368	250	
32	Telengana	6740	6369	3016	3353
33	Uttar Pradesh	19180	19180	5197	
34	Uttrakhand	918	918	Nil	
35	West Bengal	9500	8075	851	515
	Total	1,41,064	1,27,531 (90%)	34,752 (27%)	4,515

Annexure II: Cities Generating Wastes in between 200-1000 TPD

S. No	Cities	Estimated Waste Generation (t/d)	S. No	Cities	Estimated Waste Generation (t/d)
1	Vishakhapatanam	350	36	Gwalior	300
2	Patna	450	37	Jabalpur	550
3	Vadodara	1150	38	Raipur	230
4	Hubli-Dharwar	300	39	Ujjain	300
5	Kochi	360	40	Ahmadnagar	250
6	Thiruvanathpuram	360	41	Akola	200
7	Indore	850	42	Amravati	250
8	Bhubaneshwar	600	43	Aurangabad	500
9	Ludhiana	850	44	Jalgaon	550
10	Coimbatore	850	45	Kolhapur	250
11	Madurai	450	46	Latur	250
12	Allahabad	450	47	Malegaon	260
13	Varanasi	500	48	Nasik	500
14	Guntur	250	49	Solapur	350
15	Elluru	200	50	Cuttack	250
16	Kakinada	200	51	Rourkela	250
17	Kurnool	220	52	Amritsar	600
18	Nellore	250	53	Jallandhar	360
19	Nizamadabad	200	54	Ajmer	420
20	Rajamundhry	300	55	Bikaner	230
21	Vijaywada	550	56	Jodhpur	550
22	Warangal	500	57	Kota	400
23	Guwahati	600	58	Trichy	240
24	Dhanbad	180	59	Thirunelveli	270
25	Jamshedpur	300	60	Aligarh	300
26	Ranchi	150	61	Bareily	450
27	Bhavnagar	300	62	Ghaziabad	500
28	Jamnagar	320	63	Gorakhpur	340
29	Rajkot	450	64	Meerut	500
30	Faridabad	400	65	Moradabad	250
31	Belgaum	200	66	Saharanpur	250
32	Mysore	350	67	Durgapur	280
33	Kannur	350	68	Chandigarh	370
34	Kozhikode	250	69	Salem	200
35	Durg	300	70	Dehradun	270

Annexure III: Cities Generating Wastes in between 100-200 TP

S. No	Cities	Estimated Waste Generation (t/d)	S. No	Cities	Estimated Waste Generation (t/d)
1	Anantpur	110	31	Bharatpur	100
2	Khammam	270	32	Bhilwara	110
3	Tirupati	270	33	Ganganagar	110
4	Arrah	100	34	Pali	120
5	Bhagalpur	140	35	Sikar	100
6	Bihar Sharif	120	36	Tonk	100
7	Bokaro(Steel)	160	37	Udaipur	120
8	Gaya	150	38	Dindugul	120
9	Muzaffarpur	100	39	Nagarcoil	120
10	Panipat	120	40	Thanjavur	120
11	Rohtak	130	41	Tuticorin	120
12	Bellary	160	42	Firozabad	120
13	Davengere	140	43	Jhansi	180
14	Gulbarga	160	44	Mathura	140
15	Mangalore	140	45	Muzaffarnagar	140
16	Thirussur	130	46	Rampur	120
17	Murwara(Katni)	120	47	Shahjahanpur	130
18	Ratlam	120	48	Asansol	120
19	Sagar	100	49	Bardhaman	140
20	Chandrapur	100	50	Kharagpur	100
21	Dhule	130	51	Medinipur	180
22	Ichalkaranji	170	52	Ondal	120
23	Nanded	160	53	Pondicherry	160
24	Prabhani	100	54	Jammu	180
25	Sangli	170	55	Srinagar	140
26	Bhivandi	180	56	Shimla	180
27	Berhampur	100	57	Shillong	180
28	Patiala	140	58	Aizwal	100
29	Alwar	110	59	Tirupur	120
30	Beawar	110	60	Imphal	140