Antarctic fur seal entangled in plastic sheeting. *Credit: British Antarctic Survey*

Plastic Debris in the Ocean

Every year large amounts of plastic debris enter the ocean, where it slowly fragments and accumulates in convergence zones. Scientists are concerned about the possible impacts of small plastic fragments—microplastics—in the environment. The role of plastics as a vector for transporting chemicals and species in the ocean is as yet poorly understood, but it is a potential threat to ecosystems and human health. Improved waste management is the key to preventing plastic and other types of litter from entering the ocean.

The ocean has become a global repository for much of the waste we generate. Marine debris includes timber, glass, metal and plastic from many different sources. Recently, the accumulation and possible impacts of microplastic particles in the ocean have been recognized as an emerging environmental issue. Some scientists are increasingly concerned about the potential impact of releases of persistent bio-accumulating and toxic compounds (PBTs) from plastic debris. At the same time, the fishing and tourism industries in many parts of the world are affected economically by plastic entering nets, fouling propellers and other equipment, and washing up on beaches. Despite international efforts to stem the flow of plastic debris, it continues to accumulate and impact the marine environment. To reduce the quantity of plastic entering the ocean, existing management instruments need to be made more effective and all aspects of waste treatment and disposal need to be improved.

Several common types of plastic are buoyant and have been transported by ocean currents to the remotest regions of the planet, including the Arctic and Antarctic (Barnes et al. 2010). Media attention has focused on reports of the relatively high incidence of plastic debris in areas of the ocean referred to as 'convergence zones' or 'ocean gyres'. This has given rise to the widespread use of terms like 'plastic soup', 'garbage patch' and 'ocean landfill'. Such terms are rather misleading in that much of the plastic debris in the ocean consists of fragments that are very small in size while the areas where they are floating are not, for example, distinguishable on satellite images. Nevertheless, publicity resulting from media reports and from the activities of several NGOs has helped to raise public and political awareness of the global scale of the plastic debris problem, together with the larger issue of marine litter.

Microplastics are generally considered to be plastic particles smaller than 5 millimetres in diameter (Arthur et al. 2009).

Persistent, bio-accumulating and toxic substances (PBTs) have a range of chronic health effects, including endocrine disruption, mutagenicity and carcinogenicity. A subset is regulated under the Stockholm Convention on Persistent Organic Pollutants (POPs).

Assessing the extent of the problem

It is difficult to quantify the amounts and sources of plastic and other types of debris entering the ocean. Land-based sources include poorly managed landfills, riverine transport, untreated sewage and storm water discharges, industrial and manufacturing facilities with inadequate controls, wind-blown debris, recreational use of coastal areas, and tourist activities (Barnes et al. 2009). These sources are thought to dominate the overall supply of marine debris, but there are important regional variations. For example, shipping and fisheries are significant contributors in the East Asian Seas region and the southern North Sea (UNEP/COBSEA 2009, Galgani et al. 2010). In general, more litter is found closer to population centres, including a greater proportion of consumer plastic items such as bottles, shopping bags and personal hygiene products (Ocean Conservancy 2010).

The greatest technological development of modern plastics occurred during the first half of the 20th century. Their production and use have continued to expand rapidly up to the present day (**Figure 1**). In many sectors, they have become a popular material for packaging (**Box 1**). A major benefit of their use in the food industry is that it can extend shelf life, thus decreasing the risk of infection and reducing food waste.

Ship- and platform-based sources of plastic litter in the ocean include fishing and recreational vessels, cruise liners, merchant shipping, oil and gas platforms, and aquaculture facilities (**Figure 2**).

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Box 1: Consumer plastics—uses and fate

Most packaging and products in the waste stream are made of a small group of commodity plastics, including polyethylene (PE), polypropylene (PP), polyethylene terephthalate (PET), polyvinyl chloride (PVC), polystyrene (PS) and polyamide (PA), better known as nylon (Andrady and Neal 2009, PlasticsEurope 2010). These plastics have different properties, reflecting their intended uses. Their different properties may affect their durability and fate in the ocean. For example, PE and PP are less dense than seawater and will tend to be buoyant, whereas PS, PA and PET are denser and will tend to sink. All of these plastics can be recovered and recycled if there is appropriate infrastructure and willingness on the part of the public. Collecting and recycling mixed types of plastic remains a challenge, although separation based on density difference can be effective. Consumer plastic objects often find their way to the ocean through a combination of poor waste management practices, inadequate policies and regulation, ineffective enforcement, and the attitude and behaviour of individuals.

The major drivers of plastic use are improved physical or chemical properties compared with alternatives; low cost; mass production capability; and a reduction in the use of resources. Moreover, life-cycle analysis has shown that using plastic, rather than alternatives, often results in significant reductions in energy consumption and greenhouse gas emissions in applications ranging from food containers to vehicles and aircraft (PWC/Ecobilan 2004).

The applications of plastics in consumer products are many and varied. There are also significant regional differences in their use and disposal. Polyethylene bags are commonly used in West Africa to provide safe drinking water, but they often end up in water bodies due to a lack of waste disposal facilities. In Europe, approximately 38 per cent of plastics are used for disposable packaging (Barnes et al. 2009). Quantitative data for many countries are difficult to obtain, particularly on the use and fate of single-use items such as bottles, carrier bags and food packaging.

Use of plastic materials reached approximately 100 kg per year per capita in North America and Western Europe in 2005 and is expected to increase to 140 kg by 2015. Rapidly developing Asian countries constitute the world's largest potential growth area, with current use of around 20 kg plastic per year per person estimated to increase to 36 kg by 2015 (EuPC et al. 2009). Rates of plastic recycling and re-use vary greatly, even within developed regions. For example, in 2009 more than 84 per cent of used plastics were recovered—that is, recycled or reused for energy generation—in seven EU countries, as well as in Norway and Switzerland. Several European countries recovered only 25 per cent or less (EuPC et al. 2009, PlasticsEurope 2010). Improving waste management operations is an often overlooked opportunity for innovation and job creation, especially in many developing countries, where only a small percentage of the plastics produced are recovered.

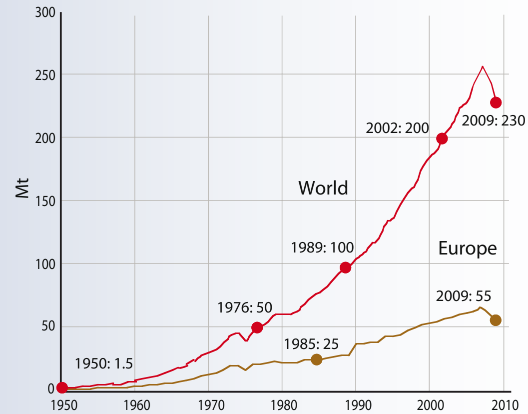


Figure 1: Growth in plastics production, 1950-2009. After five decades of continuous growth in world plastics production, there was a drop in production in 2008 due to the economic downturn. Close to 25 per cent of world production takes place in Europe. Plastics represented in the figure are thermoplastics, polyurethanes, thermosets, elastomers, adhesives, coatings and sealants, and polypropylene fibres. PET, PA and polyacryl fibres are not included. *Source: PlasticsEurope 2010*

There are large regional differences in the relative importance of these potential sources (GESAMP 2010). Discharges of plastic and other litter from ships and offshore structures are addressed under international law, but implementation and enforcement are often inadequate (NAS 2009, UNEP 2009a, Galgani et al. 2010).

Ocean circulation greatly affects the redistribution and accumulation of marine debris, as do the mass, buoyancy and persistence of the material (Moore et al. 2001). Computer model simulations, based on data from about 12 000 satellite-tracked floats deployed since the early 1990s as part of the Global Ocean Drifter Program (GODP 2011), confirm that debris will be subject to transport by ocean currents and will tend to accumulate in a limited number of sub-tropical convergence zones or gyres

A sample of plastic debris taken on board R.V. Meteor found at more than 4 200 metres water depth in the Ierapetra Basin south of Crete in Greece. *Credit: Michael Türkay, Senckenberg Research Institut Frankfurt, Germany*

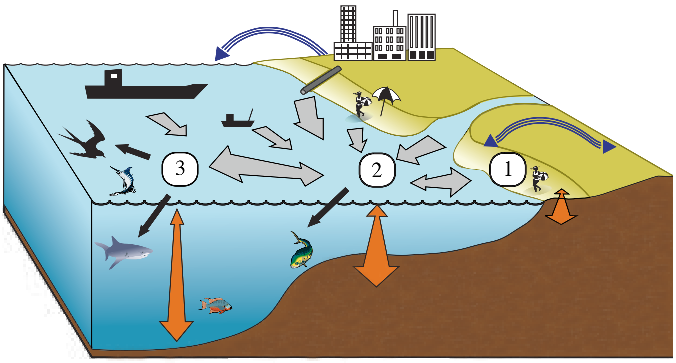


Figure 2: Main sources and movement pathways for plastic in the marine environment. Most plastic accumulates on beaches (1), in coastal waters and their sediments (2), and in the open ocean (3). Dark blue arrows depict wind-blown litter; grey arrows water-borne litter; orange arrows vertical movement through the water column, including burial in sediments; and black arrows ingestion by marine organisms. *Source: Adapted from Ryan et al. (2009)*

Attempting to stem the flow of plastic debris to the sea after heavy rain in southern California, the United States. *Credit: Bill Macdonald*

(IPRC 2008) (**Figure 3**). For this reason, the debris may be washed ashore on remote mid-ocean islands far from the source. The model simulations suggest that the debris may remain in the gyres for many years, but this does not take into account any other processes or changes in the properties of the particles.

A recent study presented data on plastic accumulation in the North Atlantic and Caribbean from 1986 to 2008 (Law et al. 2010). The highest concentrations (> 200 000 pieces per square kilometre) occurred in the convergence zones, as predicted by the model used, but there was no significant increase in concentration during this 22-year period. Although the authors speculate about possible causes, such as loss due to sinking or fragmentation to sizes not retained by the sampling net, they conclude that the results illustrate the current lack of knowledge of both sources and ocean sinks (Law et al. 2010). A proportion of the debris is thought to be ejected during the average of three years required for one revolution to be completed within the convergence zone (Ebbesmeyer and Sciglinao 2009). A study of microplastics in zooplankton samples from the Southern California Coastal Current again showed no significant change in the proportion of the microplastics during a 25-year span (Gilfillan et al. 2009). Inadequate waste management, combined with population growth and economic factors, could also affect plastic accumulation trends in other regions. However, there are no data available to confirm this yet.

For practical reasons, it is more difficult to monitor the accumulation of debris on the seabed than in the upper part of the water column. An extensive survey of the northwest European continental shelf revealed a widespread distribution of debris, mostly but not exclusively plastic (> 70 per cent), from varied sources (Galgani et al. 2000). Deep-water canyons appeared to be depositories for material from land-based sources. The quantity of fishing-related material was associated with known fishing activity. The Census of Marine Life programme, completed in 2010, reported finding plastic debris at abyssal depths. Such findings are not uncommon (Galil et al. 1995). Plastics at these depths will take much longer to fragment due to lack of ultraviolet (UV) penetration and much colder water temperatures.

Monitoring, surveillance and research focusing on plastic and other types of marine litter have increased in recent years. Nevertheless, a comprehensive set of environmental indicators for use in assessments has been lacking, as have related social and economic indicators. These types of indicators could include trends in coastal population increase and urbanization, plastics production, fractions of waste recycled, tourism revenue, waste disposal methods, shipping tonnage and fishing activities. Indicators also provide a means to measure the effectiveness of mitigation measures, such as improved waste management and the introduction of economic measures.

At the regional level, the European Commission is developing methods to assess the extent of the marine litter problem. This activity is taking place under the comprehensive Marine Strategy Framework Directive (EU 2008, Galgani et al. 2010), with indicators being produced to monitor progress towards achieving 'good environmental status' by 2020. The indicators cover the amount, distribution and composition of litter in four categories: washed

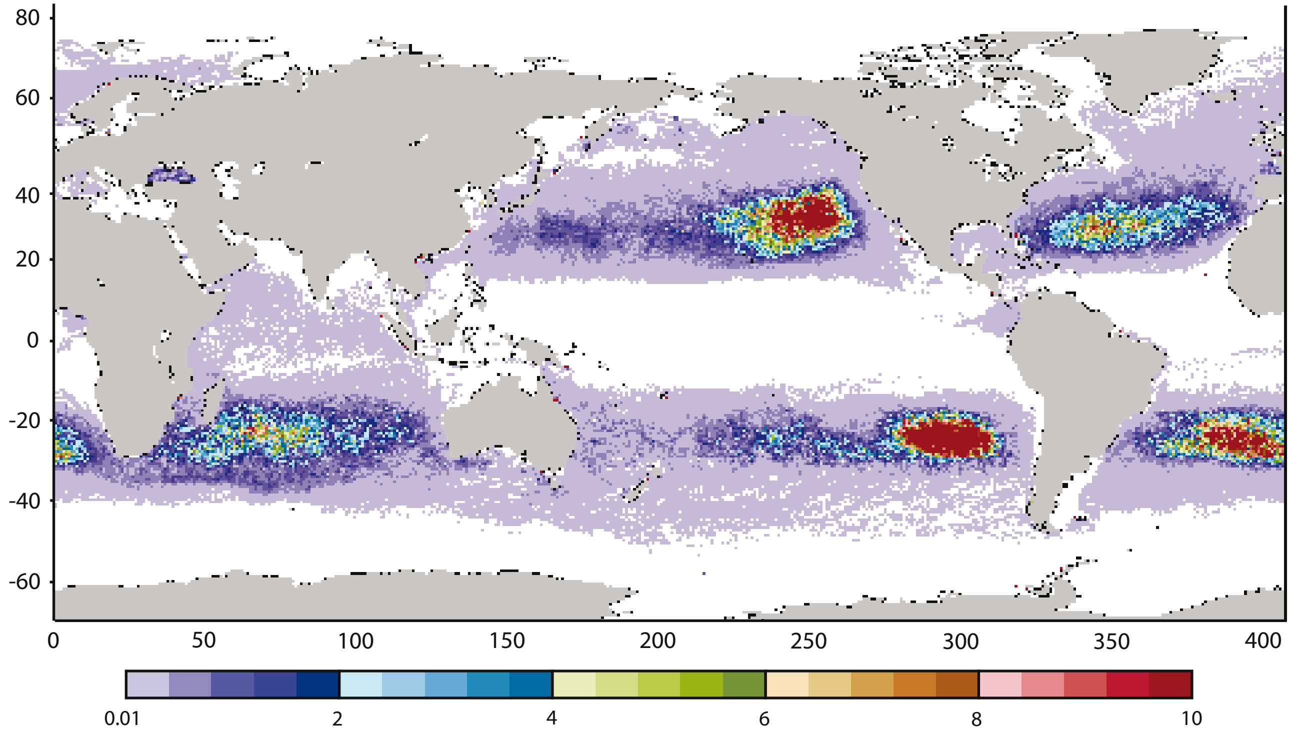


Figure 3: A model simulation of the distribution of marine litter in the ocean after ten years shows plastic converging in the five gyres: the Indian Ocean gyre, the North and South Pacific gyres, and the North and South Atlantic gyres. The simulation, derived from a uniform initial distribution and based on real drifter movements, shows the influence of the five main gyres over time. *Source: IPRC 2008*

Plastic ingested by a Laysan albatross in the Pacific. Knowing how and where marine organisms come into contact with marine debris could help in the design of management strategies to mitigate its environmental impacts. *Source: Young et al. (2009)*

ashore and/or disposed on coastlines; at sea and on the seabed; impacting marine animals; and microplastics (Galgani et al. 2010). This approach could furnish a useful example for other regional programmes with regard to producing indicators of ecological health, such as those related to the Ecological Quality Objective (EcoQO).

Routine offshore monitoring of plastic in the water column by traditional surveys tends to be costly and limited in geographical extent and frequency. This has led to an ongoing search for more cost-effective quantitative techniques. Measurements of plastic in the stomachs of stranded seabirds in the Northeast Atlantic have been used since 1977 to monitor sub-regional distributions and time trends, comparing the results with an EcoQO target (10 milligrams per bird). Fulmars, together with other species of offshore-feeding birds, such as petrels, auklets and albatrosses, are indiscriminate foragers and have been found to contain plastic objects in their guts that could be passed on to chicks (Ryan et al. 2009, Young et al. 2009). The highest levels of plastics in fulmars were found in the 1990s. Current levels are similar to those found

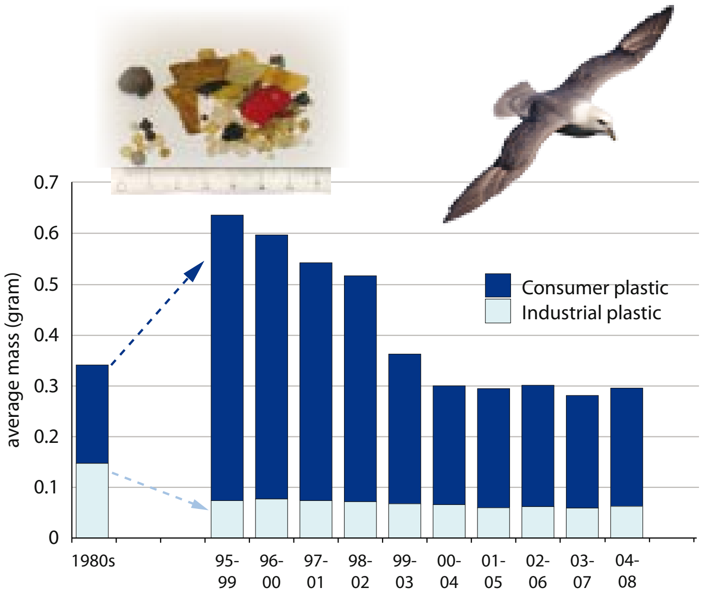


Figure 4: Consumer and industrial plastic ingested by beached fulmars in the North Sea, 1980s–2008. Since the 1980s the average mass of industrial plastic found has been halved. The intake of consumer plastic tripled in the mid-1990s, but has decreased since. *Source: van Franeker et al. (2010). Credit: Jan van Franeker, IMARES*

in the 1980s, but with no further reduction in quantity. The only change has been in composition, from industrial to consumer dominated plastics (van Franeker et al. 2010) (**Figure 4**). In a study using short-tailed shearwaters in the east Bering Sea, carried out between the 1970s and the late 1990s, Vlietstra and Parga (2002) reported a similar change in the source of plastics.

The EcoQO-related indicators provide a means of testing the effectiveness of mitigation measures. In Dutch waters, 90 per cent of litter washed ashore comes from merchant shipping or fishing (van Franeker et al. 2010). While implementation of EU legislation to improve port waste reception facilities began in the mid-2000s, no reduction in the amount of plastic in fulmar stomachs has occurred since, suggesting lack of compliance (van Franeker et al. 2010). Some additional indicators for marine debris have been developed, but they have not been widely applied.

Physical and chemical impacts

Environmental damage due to plastic and other marine debris can be defined as mortality or sub-lethal effects on biodiversity through physical damage by ingestion; entanglement in 'ghost nets' (fishing nets lost or left in the ocean) and other debris; chemical contamination by ingestion; and alteration of community structure, including the importation of alien species (Galgani et al. 2010). Exposure of plastic debris to the variety of physical, chemical and biological processes in oceans results in fragmentation and size reduction (**Box 2**). In general, potential chemical effects are likely to increase with a reduction in the size of plastic particles while physical effects, such as the entanglement of seals and other animals in drift plastic, increase with the size and complexity of the debris.

More than 260 species are reported to have been entangled in, or to have ingested, marine debris (Laist 1997, Derraik 2002, Macfadyen et al. 2009). A recent study of planktivorous fish from the North Pacific gyre found an average of 2.1 plastic items per fish (Boerger et al. 2010). Ingestion of plastics mistaken for food is well documented in seabirds, sea turtles and marine mammals and can be fatal (Jacobsen et al. 2010). Albatrosses may mistake red plastic for squid, while sea turtles may mistake plastic bags for jellyfish. However, the extent to which ingestion of plastic has an impact on species at the level of populations is difficult to quantify, especially if there are additional pressures such as loss of breeding sites or over-exploitation. Ingested particles may cause an obstruction or otherwise damage the gut lining. Alternatively, these particles may result in poor nutrition through being substituted for food (Young et al. 2009), but such effects appear to be specific to certain species. Floating plastic objects or fragments also provide a temporary 'home' or vector for invasive species, including sessile invertebrates, seaweeds and pathogens (Astudillo et al. 2009).

Concerns about the potential chemical impacts of plastic in the ocean are two-fold: besides the potential impacts of releases of additives that were part of its original formulation, there are the

Fish farms off the Pacific coast of South America are an important source of plastic debris in the region. Detached buoys could be responsible for the dispersal of associated organisms in the Southeast Pacific. *Credit: Cristián Gutiérrez, Oceana*

Box 2: Plastic's slow degradability in the ocean

Plastic, like many other materials, is quickly fouled in seawater. These items retrieved from the ocean are covered with barnacles. *Credit: Algalita Marine Research Foundation*

The degradation time for plastic in the marine environment is, for the most part, unknown. Estimates are in the region of hundreds of years. Most types of plastic cannot be considered biodegradable in this environment, as the term 'biodegradable' would only apply to those that are broken down by bacterial action or oxidation into simpler molecules such as methane, carbon dioxide and water (Narayan 2009). 'Biodegradable' or 'oxy-degradable' plastics may be broken down in industrial composters, or in landfill, in a controlled environment with a temperature consistently above 58ºC (Song et al. 2009). The temperature in most oceans is far below that, and the degradation process is therefore much slower.

Plastic in the ocean tends to fragment into smaller particles of similar composition, a process aided by the action of waves and wind. UV radiation in sunlight plays an important role in breaking down certain plastics (PP, PE). When plastic is manufactured, a UV stabilizing agent is sometimes added to extend the 'life' of certain items, also making it harder for them to break down after disposal. Seawater absorbs and scatters UV, so that plastics floating at or near the surface will break down more rapidly than those at depth. When plastic objects sink to the seabed, the breakdown process is slowed significantly since there is virtually no UV penetration and temperatures are much colder. Plastic debris has been observed on the ocean floor from the depths of the Fram Strait in the North Atlantic to deepwater canyons off the Mediterranean coast, and much of the plastic that has entered the North Sea is thought to reside on the seabed (Galgani et al. 1996, Galgani et al. 2000, Galgani and Lecornu 2004).

The surface of most plastic objects is subject to fouling in the sea due to the growth of bacteria, algae, barnacles, shellfish and other organisms. This process spans the entire size spectrum of debris, from microplastics to large single items such as buoys. A biological surface layer may affect breakdown mechanisms. Fouling may also increase the density of plastic objects, causing them to sink, with particles being redistributed throughout the whole water column and some eventually sinking to the ocean floor. Later removal of the biological surface layer by grazing organisms may cause the objects to float upwards.

potential impacts of releases of persistent, bio-accumulating and toxic substances (PBTs) that have accumulated in plastic particles over time.

The first concern relates to some of the compounds used in the manufacture of plastics, such as nonylphenol, phthalates, bisphenol A (BPA) and styrene monomers, as these can have adverse health effects at high concentrations. This may include impacts on the endocrine system involved in regulating hormone balance. Some studies have suggested that such effects might be expected on land and in freshwater ecosystems (Teuten et al. 2009). In contrast, an analysis of BPA monitoring data concluded that adverse effects would only occur to a very limited extent in highly industrialized areas (Klecka et al. 2009). The degree to which these compounds persist in the marine environment and affect marine organisms is not well quantified by scientists, and further work is needed to assess the potential impact.

The second concern relates to the accumulation of PBTs in small plastic particles (**Box 3**). All kinds of plastic debris, from nets and other fishing gear to the thousands of different consumer items that find their way to the ocean, break down into fragments that can sorb PBTs that are already present in seawater and sediments (Mato et al. 2001, Rios et al. 2007, Macfadyen et al. 2009). PBTs include polychlorinated biphenols (PCBs), polyaromatic hydrocarbons (PAHs), hexachlorocyclohexane (HCH) and the insecticide DDT, together with other Persistent Organic Pollutants (POPs) that are covered under the Stockholm Convention (Stockholm Convention on Persistent Organic Pollutants 2011). Many of these pollutants, including PCBs, cause chronic effects

Box 3: Plastic pellets

Plastic resin pellets are small granules, generally in the shape of a cylinder or disc, with a diameter of a few millimetres. These particles are an industrial raw material that is remelted and moulded into final products. They enter the ocean as a result of spills or accidental releases. Like other plastic particles, they have been shown to accumulate PBTs. In the case of thin plastic films, for example those 50 micrometres or less, it may take only a few days for this process of accumulation or release to occur (Adams et al. 2007). In the case of pellets, equilibrium between the concentration of a given compound in a pellet and in the surrounding water or sediment may take many weeks or months. Older pellets consequently tend to have higher concentrations of contaminants and have been used to map the distribution of pollution in coastal waters around the world (Ogata et al. 2009, International Pellet Watch 2011) (**Figure 5**). Their consistent size makes them a useful monitoring tool.

Transport by plastic particles does not represent a significant additional flux of PBTs on a global scale compared with atmospheric or water transport (Zarfl and Matthies 2010). However, the concentration of contaminants by microplastic particles presents the possibility of increasing exposure to organisms through ingestion and entrance into the food chain—with the prospect of biomagnification in top-end predators in the food chain such as swordfish and seals. Ingestion of small particles by a wide variety of organisms has been well reported. However, the basic information needed on the biochemical and physiological response of organisms to ingested plastics contaminated with PBTs in order to quantify the scale of the problem is currently unavailable (Arthur et al. 2009, GESAMP 2010). It is conceivable that PBTs in plastic particles will be less bioavailable than those from the surrounding water or food sources (Gouin et al. 2011).

Collected from beaches around the world, plastic pellets like these have been found to accumulate persistent, bio-accumulating and toxic substances. The pellets are used in the manufacture of plastic products and have been introduced into the ocean through accidental releases. They may also be released as a result of poor handling or waste management. While there is evidence that quantities entering the marine environment have been reduced as a result of improved industrial practices, pellets already released will persist for many years. *Credit: International Pellet Watch*

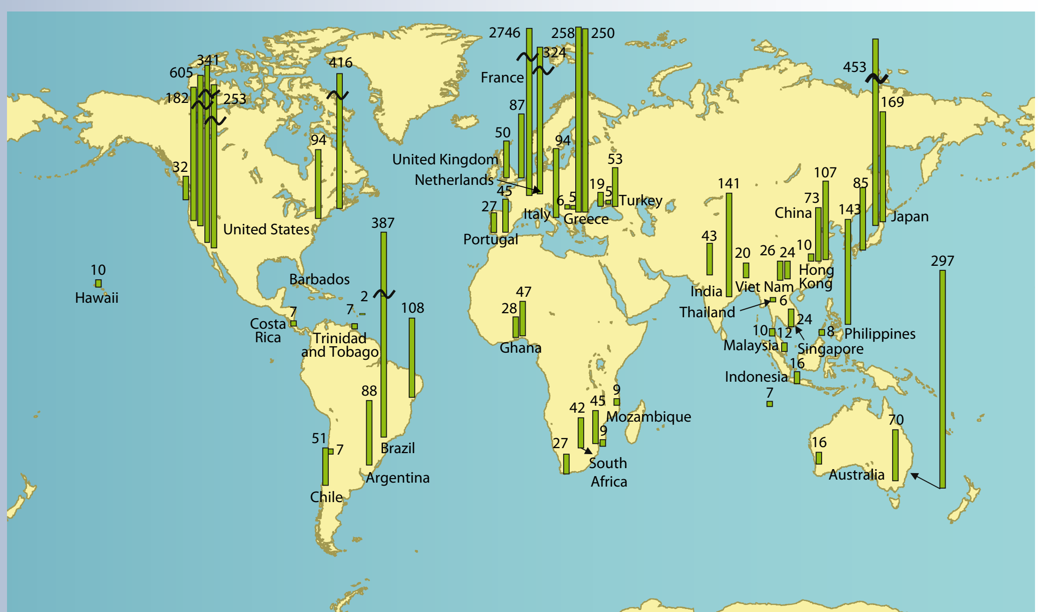


Figure 5: Concentration of PCBs in beached plastic resin pellets, in nanograms per gram of pellet. Samples of polyethylene pellets have been collected at 56 beaches in 29 countries and analyzed for concentrations of organochlorine compounds. PCB concentrations were highest in pellets collected in the United States, Western Europe and Japan. They were lowest in those collected in tropical Asia and Africa. This spatial pattern reflects regional differences in the use of PCBs. *Source: Ogata et al. (2009) with additional data provided by International Pellet Watch in 2010*

such as endocrine disruption affecting reproduction, increases in the frequency of genetic mutations (mutagenicity) and a tendency to cause cancer (carcinogenicity). Some scientists are concerned that these persistent contaminants could eventually end up in the food chain, although there is currently great uncertainty about the degree to which this poses a threat to human and ecosystem health (Arthur et al. 2009, Teuten et al. 2009, Thompson et al. 2009, GESAMP 2010).

We know that microplastics are ubiquitous in the ocean, contain a wide range of chemical contaminants, and can be ingested by marine organisms. However, the lack of certainty about the possible role of microplastics, as an additional vector for contaminants taken up by organisms, calls for caution and further research.

Social and economic effects: 'wider than the ocean'

Costs associated with the presence of plastic and other types of marine debris are often borne by those affected rather than those responsible for the problem (ten Brink et al. 2009, Mouat et al. 2010). The most obvious impacts are economic, such as loss of fishing opportunities due to time spent cleaning litter from nets, propellers and blocked water intakes. Marine litter costs the Scottish fishing industry an average of between US$15 million and US$17 million per year, the equivalent of 5 per cent of the total revenue of affected fisheries. Marine litter is also a significant ongoing navigational hazard for vessels, as reflected in the increasing number of coastguard rescues to vessels with fouled propellers in Norway and the United Kingdom: there were 286 such rescues in British waters in 2008, at a cost of up to US$2.8 million (Mouat et al. 2010).

Cleanups of beaches and waterways can be expensive. In the Netherlands and Belgium, approximately US$13.65 million per year is spent on removing beach litter. Cleanup costs for municipalities in the United Kingdom have increased by 38 per cent over the last ten years, to approximately US$23.62 million annually (Mouat et al. 2010). It is estimated that removing litter from South Africa's wastewater streams effectively would cost about US$279 million per year (ten Brink et al. 2009).

Other considerations include 'aesthetic intangible costs'. Litter can affect the public's perception of the quality of the surrounding environment. This, in turn, can lead to loss of income by local communities engaged in tourism, and in some cases by national economies dependent on tourism and associated economic activities (ten Brink et al. 2009, Mouat et al. 2010). Broken plastic, like broken glass, also has the potential to injure or greatly inconvenience beach users.

The Asia-Pacific Economic Cooperation (APEC) has reported that, in the Asia-Pacific region alone, marine debris is estimated to cost more than US$1 billion per year for activities ranging from cleanups to boat repairs. Fishing, transportation and tourism industries in many countries, as well as governments and local communities, suffer from the negative impacts of marine debris (McIlgorm et al. 2008, Ocean Conservancy 2010).

Tackling the issues, managing the problems

Despite the existence of a number of international conventions (**Box 4**), the problem of plastic and other marine debris in the ocean persists. This points to a lack of effective global, regional and national strategies to address municipal and other sources of waste. It also suggests deficiencies in the implementation and enforcement of existing regulations and standards, some of which may lack economic support.

A number of countries have taken steps at the national level to address this problem with legislation and the enforcement of regional and international agreements through national regulations. However, in many countries such initiatives either do not exist or are ineffective.

A wide variety of economic instruments can be used to help change attitudes and behaviour (ten Brink et al. 2009). To be successful, they need to be accompanied by concrete actions and effective implementation, underpinned by information, education, public awareness, capacity-building and technology transfer programmes. Examples include encouraging the development and use of appropriate reception facilities for ship-generated wastes, co-operative action within the fishing sector, consideration of life-cycles in product design to reduce plastic waste, and improvements in waste management practices.

The Global Programme of Action for the Protection of the Marine Environment from Land-based Activities

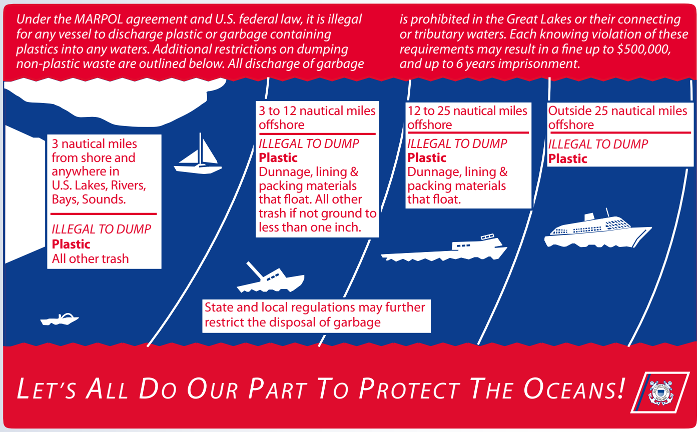
The Global Programme of Action (GPA) for the Protection of the Marine Environment from Land-based Activities, whose Secretariat is provided by UNEP, is the only global initiative that directly addresses the link between watersheds, coastal waters and the open ocean (UNEP/GPA 2011). It provides a mechanism for the development and implementation of initiatives to tackle transboundary issues. Plastic and other types of marine debris are such an issue. To help improve the knowledge base, UNEP has collaborated with the Intergovernmental Oceanographic Commission of the United Nations Educational, Scientific and Cultural Organization (UNESCO-IOC) to develop Guidelines on

Box 4: International conventions

The issue of marine debris has been addressed by the United Nations General Assembly within the context of its annual resolutions on oceans and the law of the sea and on sustainable fisheries. In 2005, this issue was also considered as a topic of focus of the sixth meeting of the United Nations Open-ended Informal Consultative Process on Oceans and the Law of the Sea. Two major international conventions specifically address marine litter in the ocean: the International Convention for the Prevention of Pollution from Ships, 1973, as modified by the Protocol of 1978 (MARPOL 73/78); and the Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter 1972 (commonly referred to as the London Convention) with its 1996 Protocol (the London Protocol). However, despite restrictions on disposal of waste based on its type and the distance from land, and a complete ban on the disposal of plastics at sea, the world's beaches and oceans continue to be polluted by plastic and other types of marine debris. The coverage of these conventions in general is considered to be adequate, but their implementation and enforcement may need to be strengthened (NAS 2009).

The purpose of MARPOL 73/78 is to control pollution from shipping by regulating the types and quantities of waste that ships discharge to the marine environment. MARPOL Annex V on the prevention of pollution by garbage from ships has been in force since 1988. Under Annex V, 'garbage' includes all types of food, domestic and operational waste, excluding fresh fish, generated during normal operation of the vessel and liable to be disposed of continuously or periodically. Disposal of plastics into the sea anywhere is strictly forbidden. Annex V also obliges governments to ensure the provision of reception facilities at ports and terminals for the reception of garbage. The International Maritime Organization (IMO) has actively encouraged countries to improve these facilities. Annex V has been under review by the IMO, and amendments to revise and update it are to be considered for adoption in July 2011 (IMO 2011).

The London Convention covers the control of dumping of wastes at sea that have been generated on land. It requires the signatories (86 states) to prohibit dumping of persistent plastics and other non-biodegradable materials, as well as certain compounds, into the sea. In addition, the 1982 United Nations Convention on the Law of the Sea (UNCLOS) sets out the legal framework within which all activities in the oceans and seas must be carried out. Part XII (Articles 192-237), in particular, concerns the Protection and Preservation of the Marine Environment. It sets out general obligations to prevent, reduce and control pollution from land-based sources, including rivers, estuaries, pipelines and outfall structures; from seabed activities subject to national jurisdiction; from activities in a designated Area, that is, the seabed, ocean floor and subsoil thereof, beyond the limits of national jurisdiction; from vessels; by dumping; and from or through the atmosphere.



Vessels in the United States are required to maintain garbage record books and shipboard management plans and to display placards such as this one, notifying crew and passengers of the requirements of MARPOL Annex V. A violation may result in a fine or imprisonment. *Credit: United States Coast Guard, reproduced in NAS (2009)*

the Survey and Monitoring of Marine Litter (Cheshire et al. 2009). In collaboration with the Food and Agriculture Organization of the United Nations (FAO), a comprehensive report on abandoned, lost or otherwise discarded fishing gear has been published (Macfadyen et al. 2009).

Regional initiatives

Regional co-operation is essential if the problem of plastic debris in the ocean is to be addressed successfully. The Global Initiative on Marine Litter, a co-operative activity of UNEP/GPA and the UNEP Regional Seas Programme (UNEP/RSP), has organized and implemented numerous regional marine litter activities. Regional Seas programmes involved comprise Black Sea, Wider Caribbean, East Asian Seas, Eastern Africa, South Asian Seas, ROPME Sea Area, Mediterranean, North-East Pacific, North-West Pacific, Red Sea and Gulf of Aden, South-East Pacific, Pacific, and Western Africa. Activities have included collaboration with the Ocean Conservancy's International Coastal Cleanup (ICC) to raise awareness of the marine debris issue in regions and to encourage greater public education and engagement. The 18 Regional Seas Conventions and Action Plans could serve as platforms for developing common regional strategies and promoting synergies, mainly at the national level, to prevent, reduce and remove marine litter (UNEP 2009b).

Providing incentives for portside disposal of ship-generated waste is one practical means of curbing waste discharges at sea. In addition, providing economic incentives to dispose of waste

Measures to reduce the amount of marine litter entering the ocean can be made more effective by providing ports with adequate and inexpensive reception facilities for disposal of vessel garbage, such as this container at the port of Bristol, United Kingdom. *Credit: Bristol Port Company*

onshore can prevent illegal discharges. An example is the no-special-fee system for oils and waste discharged to port reception facilities in the Baltic Sea Area (HELCOM 2011).

National and local initiatives

Ways to better understand and ultimately reduce the flow of plastic debris to the ocean are being sought through a range of national and local initiatives. For example, in the United States improved monitoring and assessment methods have been developed to identify and quantify the amounts and composition of marine litter. This initiative is co-ordinated by the National Oceanic and Atmospheric Administration (NOAA) and its partners. In the United Kingdom, the Waste and Resources Action Programme (WRAP) encourages businesses to reduce waste, increase recycling and decrease reliance on landfill (WRAP 2011). To help raise awareness, UNEP and NOAA are co-hosting the 5th International Marine Debris Conference in March 2011 (IMDC 2011).

Industry initiatives

The problem of plastic debris in the ocean has been recognized by a number of industry sectors. For example, regional Marine Environment Protection Associations (MEPAs) have been established by the shipping sector to preserve the marine environment through educating those in the sector, port communities and children. This initiative was started in Greece in 1982 by the local shipping community as a response to public concern about marine pollution in the Mediterranean (HELMEPA 2011). Several regional initiatives followed. They are now co-ordinated by the International Marine Environment Protection Association (INTERMEPA). The MEPAs' commitment 'To Save the Seas' includes voluntary co-operation to protect the marine environment from pollution, awareness and educational activities, promotion of health and safety standards, and enhancement of quality standards and professional competence throughout the organization's membership (INTERMEPA 2011).

The American and British plastics industries have implemented Operation Clean Sweep to reduce losses of resin pellets to the environment, particularly during their transport and shipment. Motivated by the need to comply with legislation, but also sound economics and good environmental stewardship, Operation Clean Sweep is contributing to the reduction of plastic pellets found in marine debris (Operation Clean Sweep 2011).

The Fishing for Litter campaign is an example of a low-cost voluntary activity. Developed through the Local Authorities International Environmental Organisation, it encourages fishers based around the North Sea to collect and bring to port any litter retrieved in their nets (KIMO 2011). This approach, promoted through co-operation between the industry and local government, was adopted by the OSPAR Commission under the Convention for the Protection of the Marine Environment of the North-East Atlantic in 2007. An alternative approach to reduce marine litter in the Republic of Korea has been through the Waste Fishing Gear Buy-back Project (Macfadyen et al. 2009). In South East Asia, the Green Fins project is an initiative by the diving tourism industry that promotes sustainable use of coral reefs. It includes clearing discarded fishing nets and other debris from reefs (Green Fins 2011).

NGO initiatives

Several NGOs are focusing on plastic debris in the ocean. The Algalita Marine Research Foundation has been prominent since 1997 in conducting ocean surveys and promoting research projects, initially in the North Pacific and extending into the North Atlantic and Indian Oceans (Algalita 2011). It is one of a number of NGOs that supports the 5 Gyres initiative, which is currently investigating the distribution of microplastics and POPs in each of the five main ocean gyres in conjunction with Pangea Expeditions and the UN Safe Planet Campaign (5 Gyres 2011). Another novel initiative is the Travel Trawl. Using equipment loaned to them, citizen scientists collect samples of plastic debris during their own sailing voyages and report their findings to the Algalita Foundation (Travel Trawl 2011).

In 2009, Project Kaisei collaborated with the Scripps Institution of Oceanography to support a graduate student-led expedition to explore and analyze plastic debris in the North Pacific gyre (Scripps Institution 2009). Project Kaisei is testing ways to remove some of the plastic in the ocean using low-energy catch methods. Further studies are designed to determine types of remediation or recycling that could be applied to collected plastic material, including derelict fishing nets, so that there will be some potential for economic value creation to subsidize cleanup efforts (Project Kaisei 2011).

The annual International Coastal Cleanup organized by the Ocean Conservancy is the world's largest volunteer effort to collect information on the amounts and types of marine debris. In 2009, 498 818 volunteers from 108 countries and locations collected 3 357 tonnes of debris from over 6 000 sites (Ocean Conservancy 2010) (**Figure 6**). Plastic bags, the second most common item removed, have much greater potential impact than the number one item (cigarettes/cigarette filters). Clean Up the

Raising awareness and bridging the gap between science and policy making. Debate on plastic in the ocean as part of the Royal Geographical Society (with IBG) 21st Century Challenges discussion series in London, the United Kingdom. Panelists included an oceanographer, a representative of the plastic industry and the skipper of the *Plastiki*. *Credit: Royal Geographical Society*

Rank	Debris item	Number
1	Cigarettes / cigarette filters	2 189 252
2	Bags (plastic)	1 126 774
3	Food wrappers / containers	943 233
4	Caps, lids	912 246
5	Beverage bottles (plastic)	883 737
6	Cups, plates, forks, knives, spoons	512 517
7	Beverage bottles (glass)	459 531
8	Beverage cans	457 631
9	Straws, stirrers	412 940
10	Bags (paper)	331 476
	Top 10 total debris items	8 229 337

Figure 6: Top ten marine debris items removed from the global coastline and waterways during the 2009 International Coastal Cleanup. The list shows that plastic is part of the overall marine litter problem, but it does not include some less common and potentially more hazardous plastic items such as discarded fishing nets. *Source: Ocean Conservancy*

World is another initiative started by an individual motivated to take action by the amount of plastic debris he discovered when sailing in the open ocean. Since 1993, it has developed into an international programme designed to encourage communities to work together to make a positive difference to the environment (CUW 2011).

In 2010 the *Plastiki*, a 60-foot catamaran made of 12 500 reclaimed plastic bottles and other recycled PET plastic and waste products, sailed from San Francisco to Sydney, Australia, to raise awareness of plastic in the ocean (Plastiki 2011). The voyage of the *Plastiki* took place two years after a 5 Gyres/Algalita project during which the *Junkraft*, made of 15 000 reclaimed plastic bottles, sailed through the North Pacific gyre (Junkraft 2008).

Looking ahead

More information is clearly required about the sources, distribution, fate and potential impact of plastics in the marine environment. This is particularly true in the case of microplastics, as we lack adequate knowledge of their potential physical and chemical effects on marine organisms. Information is needed at local, regional and global scales, as sources, circumstances, capabilities and mitigation strategies at each scale will vary. Solutions need to be part of comprehensive programmes to improve waste management generally: that is, waste collection and disposal infrastructure, waste management practices, and enforcement. Such programmes could include improved design and application of single-use plastics, increased consumer awareness and behavioural changes, improved recycling and re-use, and the introduction of economic instruments to reduce littering and promote secondary uses of plastic debris (ten Brink et al. 2009). Innovative technologies in the recycling sector present possibilities to recycle a greater proportion of waste and should be encouraged. Part of the answer may lie in the application of the concept of extended producer responsibility, according to which a producer's responsibility for a product is extended to the post-consumer stage of the product's life cycle (OECD 2006).

If plastic is treated as a valuable resource, rather than just as a waste product, any opportunities to create a secondary value for the material after its first intended use will provide economic incentives for collection and reprocessing. For example, in several European countries a large proportion of waste is used for energy generation in modern high-temperature furnaces, with strict emissions control. New technologies for turning plastic into diesel and other fuels could be a promising option for reducing the amounts of many types of plastic that are unlikely to be recycled, as well as new waste management revenue streams for communities and municipalities. However, it should be recognized that some smaller countries, particularly small island developing states (SIDS), have specific problems attracting investment and developing the appropriate infrastructure to deal with waste generated, for example, by the tourism industry.

Successful management of the global marine litter problem will require the development and implementation of effective policies and measures, supported by international and regional treaties and conventions—with decision-makers giving marine litter a higher profile in national environmental protection regulations and development plans. It will be especially important to use education and outreach programmes to encourage key user groups, industry sectors and the general public to modify behaviour and assume greater personal responsibility for their actions. Key user groups include individual fishers and their associations, sailors, tourists, consumer groups, sporting bodies, cruise operators and hoteliers. Tackling the plastic waste issue will demand political commitment, investment and an integrated approach at all levels of society, in order to prevent litter from reaching the ocean from sea- and land-based sources and to move towards a cleaner ocean, reducing the many pressures and impacts on biodiversity and, at the same time, greatly reducing related social and economic costs.

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