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The ocean plastic pollution challenge: towards solutions in the UK

DR ERIK VAN SEBILLE, DR CHARIKLEIA SPATHI AND ALYSSA GILBERT

Headlines:

- Plastic pollution is ubiquitous in the ocean but causes the most serious harm near coastlines and during its journey towards open waters. Existing in a variety of shapes and sizes, plastic litter harms marine life and incurs a cost on coastal economies.
- We know enough about the damage done by oceanic plastic pollution to act now. However, solutions require concerted action by a range of stakeholders. The most promising solutions include:
  - Managing plastic waste at source, for instance by raising awareness amongst the public of the harm caused by plastic pollution as well as the economic and intrinsic value of plastic materials.
  - Developing and expanding the use of plastics that truly degrade in the ocean.
  - Managing waste and litter streams better: eliminating unnecessary products, ensuring adequate waste management systems are in place, setting up a circular economy for plastic products and waste where possible, boosting recycling, and incinerating unrecyclable plastic waste for energy in conjunction with the development of carbon capture and storage technology to balance the trade-off with greenhouse gas emissions.
  - Using alternative materials to plastic where possible, such as substituting the microbeads in the cosmetics for non plastic alternatives.
  - Cleaning up existing plastic pollution, with a focus on waterways, sewerage plants and coastlines.
- To achieve these solutions, the appropriate policy frameworks and mechanisms need to be in place. A legislative framework exists, but will require regular reviews and improvements to reduce the plastics in our environment.
- Our modelling shows that plastic pollution from the UK floating on the ocean ends up in the Arctic, where it puts further pressure on an already stressed ecosystem.
- Action should come first, but further scientific research in a number of areas will help pinpoint the most effective actions and create new solutions (e.g. drawing on physics, biology, ecotoxicology, materials science, engineering, and psychology).

Contents

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Introduction

Plastics are a major source of global marine pollution. Once plastic particles reach the marine environment, wind and global ocean currents can spread them around the world. As a result, plastics are dispersed across all oceans, and can be found in remote locations such as the Arctic, Southern Ocean and deep oceans[1,2]. Ocean plastic pollution is an alarming issue due to its persistence, complexity, steady growth and the pervasive impacts it has on all aspects of ecosystems. The problem requires holistic environmental remediation solutions at a global scale.

Ocean plastic pollution has received increased attention in recent years. There have been prominent advances in primary research as well as amendments in EU legislation, notably the Marine Strategy Framework Directive. High-level statements such as the Berlin declaration in 2013[3] and the G7 Leaders' statement in 2015[4] singled out ocean plastic pollution, helping to push this issue up the international agenda. The United Nations Environment Programme (UNEP) leads a programme on marine litter, and is supported by, amongst others, the Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection (GESAMP).

This paper provides a summary of the scientific knowledge to date on the nature of the ocean plastic pollution challenge, current legislation and solutions from a UK perspective, and some reflections on what actions are needed now.

Where do plastics in the ocean come from?

What is plastic and how much do we use?

Over the past 50 years, plastic as a material has evolved remarkably. Innovation in the plastic industry has led to new, low-cost, synthetic polymer resin formulations (i.e. plastics) that are versatile, durable and resistant to external shocks. Globally, 311 million tonnes of plastic were produced in 2014, 4% more than in 2013[5,6]. Major end-applications for plastics include packaging, building and construction materials, automotive components, electrical and electronic equipment, agriculture, and medical equipment (Figure 1).

In Europe, plastics consumption is dominated by Germany (24.9%), Italy (14.3%), France (9.6%), UK (7.7%) and Spain (7.4%), which together account for more than two thirds of total plastics consumption in the EU-28. Plastic consumption per capita varies significantly within the EU-28, ranging from 136 kg/capita in Western Europe to 48 kg/capita in Central Europe. Looking outside Europe, plastic consumption rates range from 139 kg/capita in the NAFTA countries (USA, Canada and Mexico) down to the lowest consumption of 2-3 kg/capita in Middle East, Africa and Asia (excluding Japan) (Figure 2)[8]. Notably, global plastic consumption has risen exponentially since 1980, with this growth driven primarily by what were historically the world's moderate plastics consumers: Asia (excluding Japan), Central Europe and Latin America. This trend is the result of population growth, expanding industrial production and changes in consumer trends in these economies[9].

Box 1: Increasing recycling rates

Increasing plastic production has not been mirrored by a corresponding increase in recycling rates. In Europe, despite stringent legislation and advanced waste management systems, only ~30% of a total of 25.8 million tonnes of waste plastics generated in 2014 were recycled. The re-processing of plastics is often technically infeasible and/or economically non-viable. This is due to ambiguous sorting criteria of waste plastics, which are often mixed with other recyclables, as well as variability in the chemical and physical characteristics of waste plastics.

Energy recovery from plastics via incineration is the preferred treatment option for non-recyclable plastics in European countries (although this treatment may increase emissions of the greenhouse gas carbon dioxide), where appropriate infrastructure is available. Landfilling is still one of the leading waste plastics management options in many European countries[6,7].

The UK, in alignment with the EU's Waste Framework Directive, set targets for the recycling of post-consumer packaging plastics at 52% for 2016, rising to 57% for 2017. Furthermore, under the producer responsibility regime for packaging, plastic packaging producers have the legal responsibility to recycle and recover a proportion of their products at the end of their life.

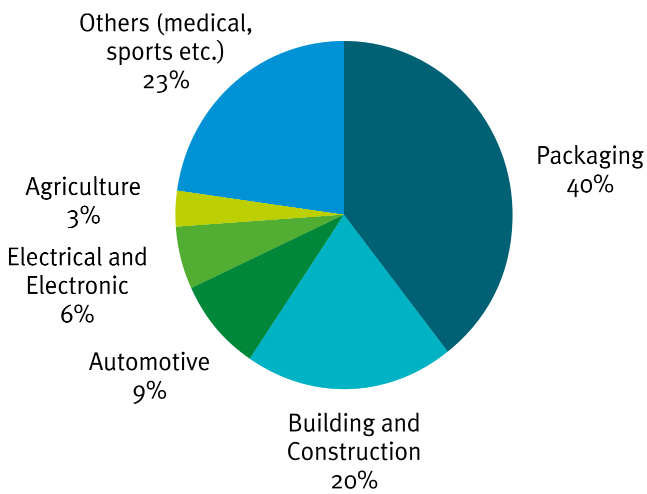
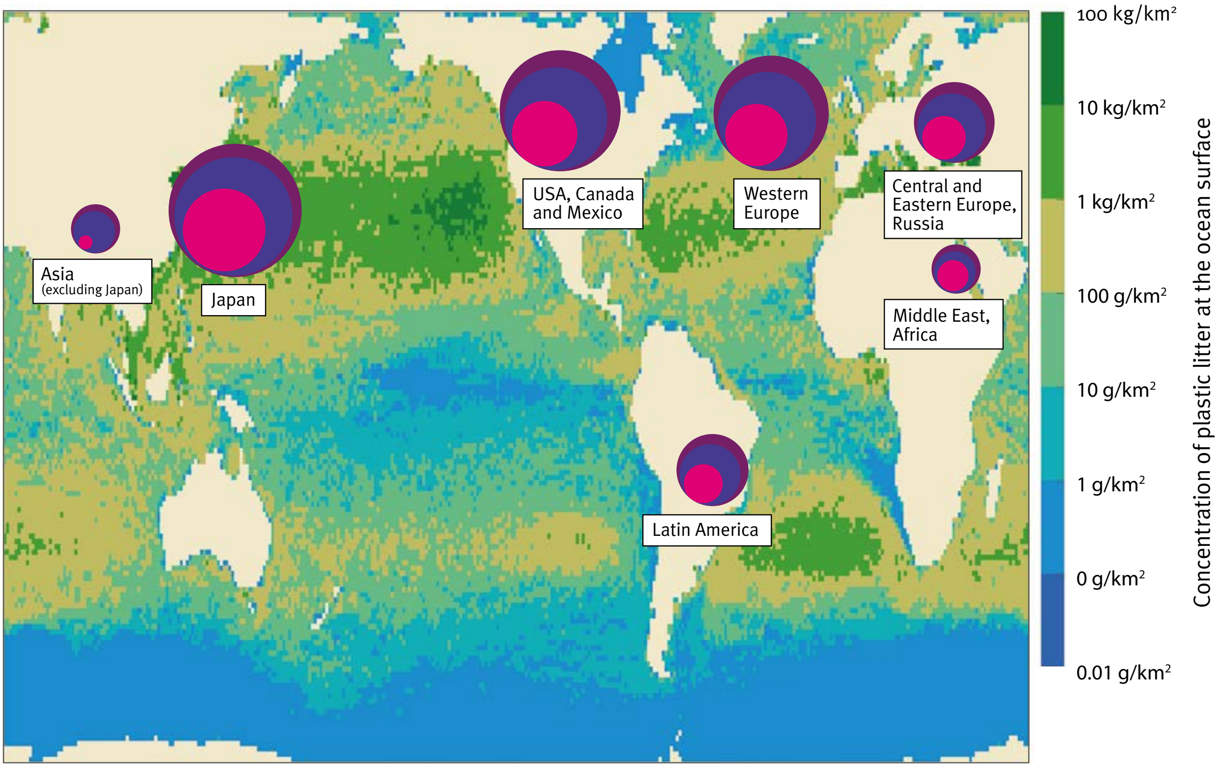


Figure 1: Global plastics consumption in Europe by market segment[6].



Consumption of plastic materials per capita

Global consumption of plastic materials by region 1980 to 2015 (in kilograms per capita)

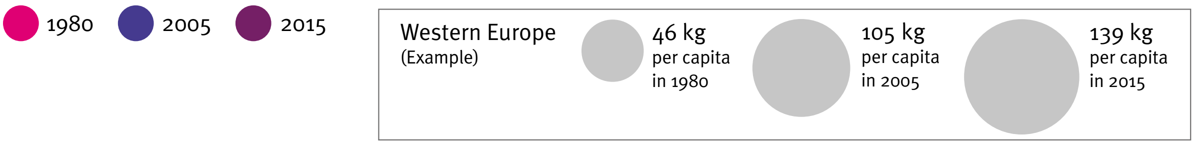


Figure 2: Global plastics consumption per capita[6] and concentration of plastic at the ocean surface[30].

Sources of marine plastic

According to what is currently the only available estimate, 80% of plastic pollution originates from land-based sources with the remainder coming from ocean-based sources. The accuracy of this figure is however subject to uncertainty since it predates the introduction of stricter controls on pollution at sea and is therefore in urgent need of updating[10]. While there is a severe dearth of information on how different sources contribute to the total amount of plastic entering the ocean, the major land-based sources are[10-12]:

- **Illegal dumping and inadequate waste management:** In the absence of effective landfills, fragments of plastic from open dumping grounds may be blown into streams, rivers or directly into the ocean. Waste can also escape whilst being collected or transported to landfill sites if waste management procedures are inadequate. In some nations without formal waste disposal services, rivers are sometimes used to dispose of waste.
- **Industrial activity:** Inadequate disposal of products, or loss during production and transport may result in plastic waste being released into streams, rivers or the ocean.
- **Insufficiently filtered wastewater:** Wastewater treatment plants filter effluent, however very small plastic particles (microplastics), such as cosmetic microbeads or fibres from clothing, cannot all be filtered out, making wastewater treatment plants a significant source of microplastic pollution.
- **Coastal littering:** Beachgoers may leave litter behind, which can include cigarette butts, food and beverage packaging, and plastic beach toys.
- **Discharge of storm water:** During storms, runoff water can pick up municipal waste, waste from dumpsites, street litter or even landfill waste. This litter is then discharged into streams, rivers or directly into the ocean via the drainage network.
- **Combined Sewer Overflows (CSOs):** In the event of heavy rainfall, when combined sewer systems (carrying wastewater and stormwater) are over capacity, mixed sewerage and stormwater may be released untreated into nearby rivers or the ocean.

- **Natural disasters:** Extreme events can result in almost any kind of waste being released into the ocean. Although uncommon, such events can cause substantial environmental impacts. In 2011 for instance, Japan's Tohoku tsunami produced a quantity of floating debris comparable to 3,200 years' worth of 'normal' debris input[13].

Boats, ships and offshore industrial platforms are also potential sources of marine debris. The major ocean-based sources are[11]:

- **Fishing:** Boats may accidentally lose or deliberately dump fishing equipment (nets, lines and rope, etc) into the ocean.
- **Shipping:** Cargo ships may discharge litter into the ocean by accident.
- **Offshore oil and gas platforms, undersea exploration:** Like with shipping, litter can accidentally be released into the ocean during any type of operation at sea.

It is estimated that 2 billion people around the world still have inadequate access to solid waste management services[12]. In the absence of changes to current waste management approaches, the flux of land-sourced plastics into the oceans is projected to continue increasing exponentially over the next decade, driven by global population growth and plastic consumption trends[14]. In contrast, plastic pollution originating from ocean-based sources should decrease if ocean users adhere to international regulations prohibiting the dumping of plastic at sea[15].

What types of plastic end up in the ocean?

Plastic debris can be classified according to its size into mega-, macro-, meso-, micro- and nanoplastics, although there is no officially adopted nomenclature[16]. Differentiating between these is important as the size of plastic particles determines their impacts.

Mega-, macro- and mesoplastics range in size from a few metres down to 5 mm. These items can be identified by the naked eye and include mostly wrappers, drink containers, single-use plastic bags, cigarette butts and medical and personal hygiene items such as diapers and syringes. Household appliances, tyres and even car parts can also be found in coastal areas, although rarely. In addition, large volumes of mega- and macroplastic debris originate from ocean-based sources and include a variety of fishing equipment, primarily in locations with intensive fishing activity[17]. The fate of floating plastic items relates to their size and buoyancy characteristics along with local wind and wave patterns[18].

Under the action of ocean waves, winds and ultraviolet (UV) light, larger pieces of plastic break down into smaller fragments. Microplastics that are the product of weathering (see below), are referred to as secondary microplastics, as opposed to primary microplastics. Primary microplastics include industrial 'scrubbers', microbeads in personal care and cosmetic formulations and virgin resin pellets used in the production of consumer plastics.

Nanoplastics (NPs), particles up to 100 nm in size[16], make up the least understood area of marine litter but are potentially the most hazardous. Due to the lack of appropriate detection methods it has not been possible to assess the presence of nanoplastics in natural aquatic systems. Nanoplastics are thought to come from the direct release of products incorporating nanoplastics and from the fragmentation of larger plastic particles in the environment[19]. The high surface area to volume ratio of nanoplastics may promote absorption of toxic compounds, potentially leading to toxicity to marine life once nanoplastics have penetrated into cell membranes[19].

Plastic degradation

Once plastics enter the marine environment they begin to degrade, eventually breaking down into secondary microplastic or even nanoplastic particles[20-22]. For polymers with a carbon backbone (polyethylene, polypropylene, polystyrene and polyvinylchloride), which constitute the majority of plastics, initial degradation converts the plastic polymers into smaller, more fragmented units and introduces new chemical groups to the ends of the carbon chain, changing the nature of the compound[23]. This process is followed by biotic degradation, so-called 'mineralisation', which converts the carbon atoms into carbon dioxide (CO_2) and inorganic chemicals[24]. However, moderate temperatures at the ocean surface and saline conditions mean degradation is much slower than in the air or in commercial composting facilities[25, 26]. Microorganisms, plants, algae and marine life, such as barnacles, colonise floating plastic debris, a process known as biofouling. Biofouling hinders degradation by UV light and also affects buoyancy. As microorganisms gather, the density of the plastic increases and it sinks to the aphotic (dark) and cold sediment zones of oceans, where very little degradation is expected[27]. De-fouling by microbes consuming the attached algae as the particles sink through the water column can, however, cause resuspension or resurfacing into the mid-water column or the ocean surface (Figure 3)[26]. It should be noted, however, that degradation pathways and products vary depending on the structure and chemical composition of the various plastics.

It is estimated that the longevity of plastics in oceans is of the order of hundreds or even thousands of years. However, there is very little reliable information about degradation mechanisms of highly weathered plastics in the environment[27], making it an important area for further research.

Pathways and distribution of marine plastic

Oceans occupy 71% of the planet's surface and are typically 4 km deep, making detailed mapping of plastic debris in the oceans challenging. Many researchers have reported the occurrence and concentration of marine plastics based on data collected from field studies[28-30]. Without a standardised experimental methodology in sampling and composition analysis of marine plastics, making direct comparisons between reported data sets is difficult. Nonetheless, the locations of major pollution hotspots are becoming clear.

The best-studied category of ocean plastic is that which is found floating on the surface of the ocean. There is reasonably good understanding about how ocean currents move plastic around, and how winds cause accumulation in the centres of the oceans, within the so-called gyres. However, depending on where it enters the ocean, a significant fraction of plastic may end up on the ocean surface outside these gyres.

For example, a new analysis of the pathway of plastic released from UK shorelines, modelled using the Adrift tool[31], shows that most of the floating plastic that doesn't beach ends up in the Arctic (Figure 4). It takes up to two years to reach the Barents Sea north of Norway, after which it slowly circulates around the Arctic. This analysis only considered floating plastic released from the UK (in quantities proportional to the population density within 100 km from the coast), although of course other countries also contribute to plastic in the Arctic. It has recently emerged that there is indeed a considerable amount of plastic in the Arctic[32], which adds further pressure to a sensitive ecosystem already under threat from melting ice and climate change.

The total amount of plastic floating on the ocean surface is between 7,000 and 236,000 tonnes[28-30]. The amount of plastic entering the ocean in the year 2010 alone, however, is estimated at 4.7 to 12.7 million tonnes[14], or roughly two orders of magnitude larger than the amount of plastic floating on the surface of the ocean. Even though these numbers are fairly uncertain, it is clear that a lot of plastic is somewhere else than on the ocean surface. Other reservoirs of ocean plastic include (Figure 3): the water column, ocean floor, beaches, and within marine life.

There is very little information on how all this plastic in the deep ocean, on coastlines and in biota is geographically distributed. As with the plastic on the surface of the ocean, there is likely to be a large heterogeneity of plastic distribution on scales from meters to hundreds of kilometres, leading to plastic hotspots. For this reason, it is easier to assess where plastics from the UK end up, than to assess where the plastics found on UK beaches come from. Research into the sources of plastics on UK coastlines is ongoing. Since the impact of plastic pollution depends critically on its concentration and where it is located, a much greater understanding of the global inventory of ocean plastic is needed.

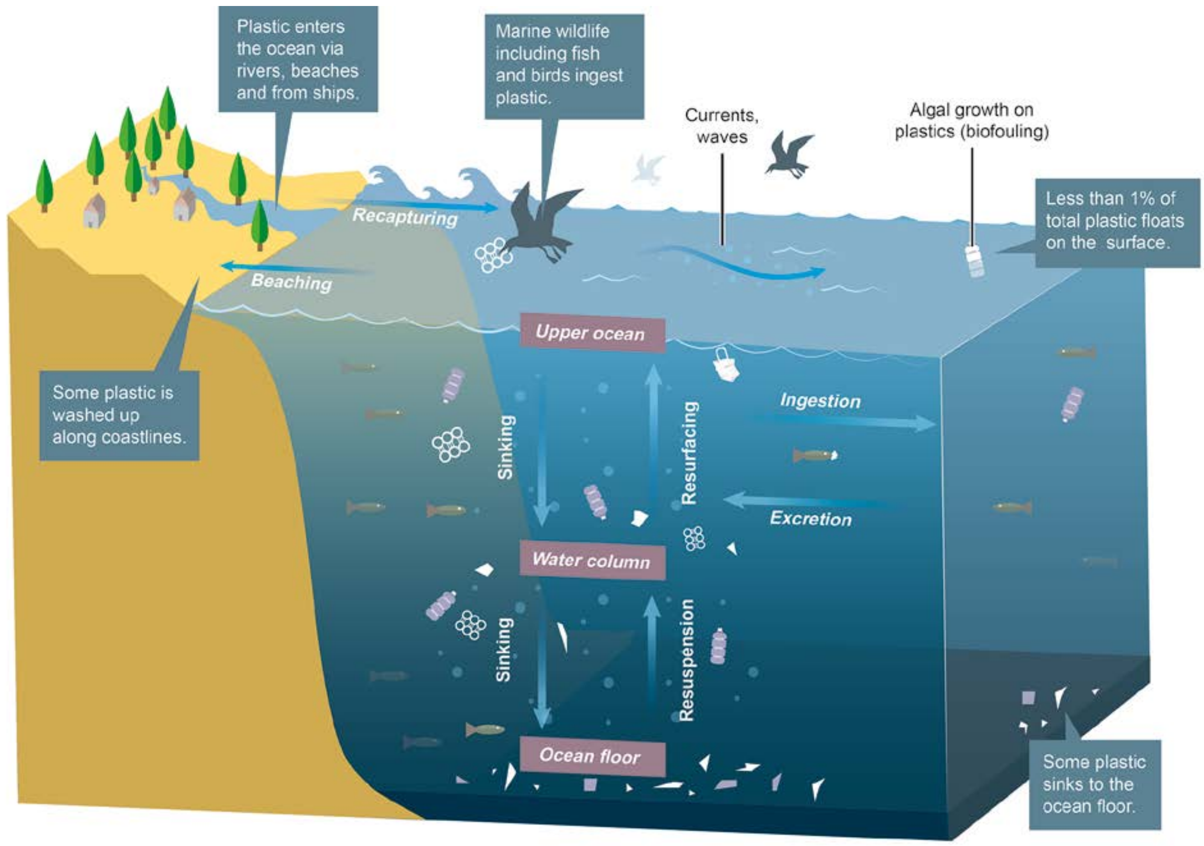


Figure 3: Processes affecting the transport of plastic in the ocean

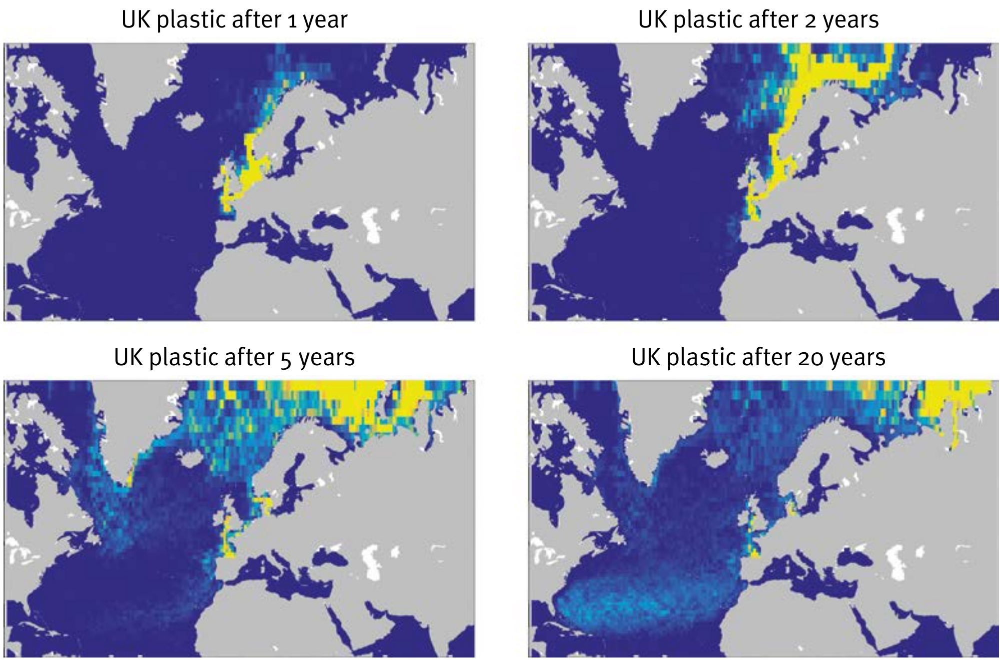


Figure 4: Movement of floating plastic released from the UK coastline, in quantities proportional to the population density within 100 km from the coast, as modelled by the Adrift tool[31].

Impacts

Plastic pollution in the ocean can have a wide range of environmental, social and economic impacts.

Environmental impacts of marine litter

Ocean plastic pollution places additional pressure on ocean ecosystems that are already severely strained by the impacts of human action[33]. These existing stresses include acidification and warming due to carbon dioxide emissions, overfishing, and pollution by heavy metals and persistent organic pollutants.

While the complete scale, extent and spatial distribution of the environmental impact of plastic is unknown, there is clear evidence from field- and laboratory-work that plastic debris threatens marine life and ecosystems in a variety of ways:

- **Ingestion:** The ingestion of plastic litter has been reported to date in over 250 marine species[34]. The main impacts of ingestion include: physical damage or blockage of the intestinal tract, which can lead to infection, starvation and potentially death; reproductive and other health disorders due to the uptake of polychlorinated biphenyl (PCB)-contaminated plastic fragments acting as a vehicle for PCBs into the marine food chain[1, 24, 35]; and energy effects resulting from carrying around the additional weight of ingested plastic (mainly in seabirds)[36]. Microplastics are of great concern because they can concentrate persistent organic pollutants (POPs) such as PCBs and dichlorodiphenyltrichloroethane (DDT, an insecticide), which can concentrate further as they move up the food chain, a process known as biomagnification.
- **Entanglement and ghost fishing:** Entanglement in nets, ropes and other debris can be fatal to marine animals. Abandoned fishing gear can continue to 'ghost fish' for long periods of time while in the marine environment[37].
- **Transport of non-native and invasive species:** Floating litter can act as a vector for the transport of species, with slow travel rates providing time for species to adapt to the changing environmental conditions. The introduction of non-native species through this transport mechanism can have detrimental effects on marine species diversity[38].

The scientific literature shows that the environmental impacts of plastic pollution tend to be largest in regions where the ecosystems are most complex and the species diversity and abundance is greatest. These regions tend to be near coastlines, in the high latitudes, and along the Equator. The accumulation zones in the middle of the ocean are relatively low in species diversity and abundance, and therefore plastic is expected to do relatively less overall harm there.

Social impacts of marine litter

- **Reduced recreational opportunities:** Coastal areas, beaches and oceans are used by recreational users for swimming, diving and a number of water sports. Plastic pollution could discourage such users from visiting affected areas.
- **Loss of aesthetic value:** A coast littered with plastic does not look as pretty and welcoming as a pristine beach[39].

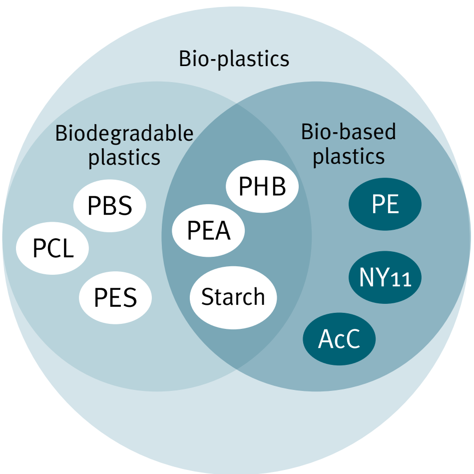
Public health and safety impacts

- **Navigational hazards:** Entanglement of anchors in abandoned fishing gear and fouling of a vessel's propeller have, in the past, been the cause of vessel breakdowns and in extreme cases, led to loss of human lives.
- **Hazards to swimmers and divers:** Incidents involving entanglement of swimmers and divers can have associated health risks.

The economic implications of marine litter

The impacts described above all have economic implications. Many of these economic impacts relate to lost or reduced revenue. In particular, there are lost revenues associated with a decline in tourism and losses to fisheries and aquaculture. In addition, the broader shipping industry may see reductions in revenues due to vessel damage and downtime, removal and management in harbours and marinas, and emergency rescue operations to vessels affected by marine litter[40].

There is also a range of direct costs associated with plastic waste, such as the clean-up costs associated with removing litter from beaches. Local authorities, community groups, civil society organisations and individual landowners often incur these costs. Where waste becomes more widespread, the cost of clearing up might be paid by a range of different groups. There are other direct costs also incurred by the fishing industry, where damage occurs to property and equipment.



PBS,Polybutylene succinate, is used in agricultural mulching films and packaging
PCL, Polycaprolactone, is used for 3D printing, biomedical applications and by hobbyists
PES, Polyethersulfone, is used in films
PEA, Polyesteracetals, is used in disposable packaging
Starch is used in packaging and bags
PHB, Polyhydroxybutyrate, is used in medical sutures
PE, Polyethylene, is used in packaging, containers and pipes
NY11, Nylon 11, is used in high-performance applications

Figure 5: Different types of bio-plastics. Bio-plastics can be both bio-based and biodegradable. (Adapted from: UNEP, 2015[12]).

Box 2: The potential of biodegradable plastics and bio-plastics

Given that it will not be possible to completely prevent plastics from entering the oceans, a large amount of recent research focuses on synthesising plastics that decompose relatively fast in the natural environment. Emerging 'green' formulations of plastic, such as biodegradable plastics, can enhance the degradation of plastics, reducing their environmental impacts at end of life, in comparison to conventional fossil fuel-derived plastics. These new plastics could deliver higher composting rates, increased organic content degradation in landfills, reduced energy requirements for their manufacture and reduced greenhouse gas (GHG) emissions when they biodegrade[41].

Biodegradable plastics are often mistakenly confused with bio-plastics. A bio-plastic can be entirely, or partly, derived from renewable resources such as corn, potatoes, rice, soy, sugarcane, wheat and vegetable oils[42,43], but is otherwise chemically equivalent to the fossil fuel-based 'normal' plastic. The label 'bio-plastic' therefore does not say anything about its degradability. The main types of bio-plastics classified according to biodegradability criteria are given in Figure 5. Table 1 sets out the advantages and disadvantages of bio-plastics.

A shorter degradation time in the marine environment reduces the chances of biodegradable plastics being ingested by marine species. However, faster degradation also releases chemical additives from the plastics more rapidly, resulting in higher concentrations of chemicals. To date, there is no balance of scientific proof to show that biodegradable plastics reduce the risks posed by marine litter[44].

Table 1: Advantages and disdvantages of bio-plastics

Advantages of bio-plastics
• Reduced greenhouse gas emissions compared to petro-plastics, process- and material-specific. • Reduced embodied carbon dioxide • Reduced leaching of toxic constituents at end-of-life • Direct bio-conversion into compost in industrial composting facilities
Disadvantages of bio-plastics
• Higher costs of production compared to petroleum-based plastics • Separate sorting required to avoid cross-contamination of the recycling stream • Acidification of regular compost • Increased quantities of starch-based biodegradable plastics in waterways can cause pollution due to their very oxygen-intensive breakdown process. • Adverse littering trends due to the belief that biodegradable plastics will disappear quickly.

Table 2: Possible measures for mitigating plastic pollution at different stages of the plastics life cycle (adapted from Veiga *et al*, 2015[40])

	Design/Production	Use/Consumption	Collection/Transfer	Treatment/Recycling	Clean up
Packaging	Packaging tax	Plastic bag tax	Deposit-refund scheme for drink containers and packaging		
	Redesign caps/lids	Public spots for water refills	Improvement of wastewater treatment plants to retain microplastics from urban and industrial effluents		Removal of marine litter in sensitive areas
	Eco-tax on specific plastics	Develop certification schemes			
	Reduce packaging by selling products in bulk and reusing		Sorting of municipal waste and incineration of non-recyclables		Regular beach clean up campaigns
Construction	Use of alternative biodegradable building materials		On-site collection, sorting and valorisation of Construction & Demolition (C&D) waste		Collection and removal of old or abandoned nets for recycling and incorporation in new products (e.g. Net-Works)
	Apply 'design for deconstruction' methods in materials design	Sustainable use of natural materials for insulation (e.g. seaweed)			
Domestic	Awareness campaigns for proper disposal of plastic waste, including labelling (e.g. Bag it, Bin it, UK)				Clean ups at river mouths Voluntary beach clean up campaigns (e.g. Let's Clean up Europe)
			Sorting of household waste and incineration of non-recyclables		
Transport	Strategies for Extended Producer Responsibility (EPR), requiring producers to be responsible for the entire life-cycle				
	Use of organic fillers in automotive plastics (e.g. tomato skins used by Ford)		Free take-back services for End-of-Life Vehicles (ELVs)		
			Materials Recovery Facilities (MRFs) for materials found in ELVs		
Electrical	Plastic cycle chain voluntary agreement between stakeholders to achieve a circular economy for plastics				
	Apply 'easy-to-recycle' methods in equipment design	Optimise maintenance services to extend the life expectancy of equipment	Recycling centres for the centralised collection of large devices		Fishing for Litter Program – collection of litter accidently caught during fishing operations and appropriate sorting and treatment (e.g. Glasgow, SW England)
			Community banks for the collection of small electrical devices		
Medical	Resource efficient production processes		On-site sorting of non-hazardous plastics for subsequent waste treatment (e.g. incineration of disposable gloves)		Removal of macro-waste before disposal of dredged sediments in the sea
	Use of pulp-based materials where applicable (e.g. Vernacare products)				
Others	Awareness raising activities about marine litter and potential solutions				
	Ban of microbeads in personal care products and cosmetics		Zero plastics to landfills (e.g. Germany)		
	Substitution of synthetic cigarette filters with natural materials	Pay-as-You-Throw: Municipal waste charges based on the amount of waste produced			

KEY:
- Policy instruments
- Economic incentives
- Technological innovation
- Voluntary initiatives

Solutions

What mitigation measures are available?

A considerable reduction in the amount of plastic debris entering the ocean could be achieved through a range of measures. These might include: reducing the use of disposable products and using alternatives to plastic, better product design, improved waste disposal and handling, improved waste infrastructure (e.g. drains), increased recycling rates, monitoring of pollution at source, and public awareness campaigns to curtail consumption trends and littering behaviour. Many of these measures can be encouraged through a so-called circular economy approach, where products, related infrastructure and markets are designed with the aim of eliminating waste, re-using, recycling and eventually repurposing plastics at the end of their useful life.

Deciding what constitutes best environmental practice is not always straightforward[45]. It is also important to focus resources on strategic intervention points, where action will make the most difference. The most effective intervention points are likely to be at the design stage or close to the source of the plastic pollution.

Economic signals play an important role in decisions about plastic waste management and therefore, ultimately, affect the quantity of plastic pollution in the oceans. Where virgin plastics are cheap, and also cheaper than their recycled counterparts, there are no strong economic incentives to reduce use nor to recycle. If the economic costs of plastic pollution were felt by the same people or organisations that cause the pollution (also known as the polluter pays principle), this might also prompt a reduction in marine plastic pollution.

Table 2 summarises key policies to stimulate marine litter reduction classified by industry sector[40]. Because of the scale of the challenge and the range of sectors and materials involved, a wide range of actions is needed.

Legislative context in the UK

Inside the UK, a range of international and European legislation underpins some of the measures outlined in this paper. This legislative framework, as set out in Table 3, shows that there is no comprehensive policy response to the waste plastics challenge. Notably, current legislation does not adequately cover identified land-based sources of ocean plastic pollution. In contrast, sea-based pollution is tightly regulated through a set of international conventions resulting in significant reductions in the volumes of waste entering into oceans. Following in Scotland and Wales' footsteps, a plastic bag tax (5 pence/bag) on all single-use plastic carrier bags was introduced in England in October 2015. These regulations align with the EU Directive on packaging and packaging waste, which was amended in 2015 to set a target on reducing the use of single-use plastic bags, amongst other changes, and represents the most recent waste prevention scheme specific to waste plastics. Reviews of the Welsh plastic bag tax indicate that this policy can stimulate some change, with a 71% decline in the use of single use plastic bags in Wales between 2011 and 2014[46].

Box 3: Citizens and communities taking action in the UK and beyond

Across the UK, local governments, citizens, social and environmental groups have taken an active role in preventing, monitoring and collecting plastics that cause marine pollution. Various monitoring programmes provide information on the quantity, quality and type of plastics encountered in coastal and riverine areas. Members of the public often deliver this information, following a so-called citizen science methodology. Beyond the UK, there are also a number of programmes that tackle the marine plastic pollution problem.

These types of initiatives help raise awareness of marine pollution issues and influence the behaviour of individual consumers, local communities and authorities as well as driving policy changes in collaboration with government officials.

The private sector also plays a role in tackling marine plastic pollution. In the UK, the British Plastics Federation (BPF) has launched 'Operation Clean Sweep', an initiative encouraging companies within the plastic industry to follow best practice in ensuring zero resin pellet loss into the environment[47]. Major cosmetic companies have actively worked ahead of legislation to explore alternatives to microplastic beads, such as ground apricot kernels.

Table 3: Legislative frameworks in place to solve the ocean plastic challenge

Target	Policy Instrument	Description	Relevance to plastic debris	Level of impact
MARINE ENVIRONMENT	Marine Strategy Framework Directive (2008/56/EC)	Sets qualitative descriptors for determining good environmental status (Annex I); Management and traceability measures of marine pollution (Annexes V, VI). Commission Decision on Good Environmental Status (GES) of marine waters (2010/477/EU).	Marine debris due to plastics is one of the descriptors for GES.	High
LAND-BASED SOURCES	Waste Framework Directive (2008/98/EC)	Explains when waste ceases to be waste and becomes a secondary raw material (end-of-waste criteria), and how to distinguish between waste and by-products. It introduces the 'polluter pays principle' and the 'extended producer responsibility'.	Handling of plastics should follow the four Rs as follows: Reduce, Recycle, Re-process, Recover.	High
	Landfill Directive (1999/31/EC)	Requires pre-treatment or sorting of waste prior to landfilling. Establishes technical requirements for the operation of landfills to achieve minimum environmental impact.	Separate collection of plastic recyclates can boost recycling rates and minimise wind-blown plastics.	Medium-High
	European Directive on packaging and packaging waste (94/62/EC) amended by Directive (EU) 2015/720	Lays out the framework for the sound management of packaging and packaging waste. Amendment: Focus on reducing the consumption of lightweight plastic carrier bags in the EU. Introduction of plastic bag tax by the end of 2018.	Reducing risk of packaging waste entering into the marine environment.	High
	Urban Waste Water Directive (91/271/EEC)	Regulates the collection and treatment of waste water in all agglomerations of over 2000 population equivalents (p.e.); requires the control of sewage sludge disposal and treated effluents	Effective removal of macroplastics present in sewage-related waste. Future treatment adaptations needed to address microplastics pollution.	Medium
	Waste Electrical and Electronic Equipment (WEEE) Directive (2012/19/EU)	Incentivises the creation of collection schemes where consumers return their WEEE free of charge.	Minimising plastic accumulation at landfills, facilitating recycling/ re-processing.	Low
	End-of-Life Vehicles Directive (2000/53/EC)	Sets a minimum 85 % reuse and recovery target for vehicle material achieved by 2015.	Increasing recycling of plastics used in the automotive indistry.	Low
	Restriction of Hazardous Substances (RoHS) Directive 2011/65/EU	Prohibits the placing on the market of electrical and electronic equipment (EEE) containing lead, mercury, hexavalent chromium, PBB, PBDEs or cadmium.	Potential to minimise harardous content of plastics reaching the marine environment.	Low
	Ecodesign Directive (2005/32/EC) (2009/125/EC)	Covers all environmental impacts caused by products during any phase of the life cycle. It accounts for both material and energy efficiency.	Extends lifespan of plastic products contributing to reduction of waste generation.	Low
	Plastic materials and articles intended to come into contact with food Directive (2002/72/EC)	Introduces the EU Eco-label.	Of particular interest from a plastics perspective are the bio-based products and recycling markets.	Low
OCEAN-BASED SOURCES	International Convention for the Prevention of Pollution from Ships (MARPOL 73/78)	Aims to minimise marine pollution of the oceans and seas, including dumping, oil and air pollution.	Reducing illegal dumping.	High
	London Convention for the Prevention of Marine Pollution from the Dumping of Wastes (LC '72)	Controls pollution at sea by dumping (87 signatories).	Similar impacts with those of MARPOL 73/78	High
	Port Waste Reception Facilities Regulations 2003 (to deliver EU DIRECTIVE 2000/59/EC targets)	Consolidates plans for responsible ship-generated waste and cargo residues management; ensures adequate port reception facilities are available to meet the needs of users.	Preventing plastic debris from entering oceans.	High
	Regulation on shipments of waste (1013/2006/EC)	Aims to prevent the illegal shipment of waste. Sorted, non-contaminated plastic falls within the 'green list' for transboundary shipments.	Strict criteria on plastic recyclate material maximise quality and value of waste-derived end-products.	Medium-High

Conclusions

Plastic pollution in the world's oceans is an urgent problem that we need to start tackling now. The solutions for addressing plastic pollution are available, but will require coordinated action across a number of sectors and stakeholders. Policy makers have a key role to play in creating the essential legislative framework to stimulate mitigation actions that contribute to a reduction in plastic waste at source, as well as encouraging cleaning up plastic pollution on coastlines before it does the most significant damage.

Solutions to the plastic pollution challenge will involve a combination of:

- Improved product design, taking in mind various stages of reuse, recycling and end of life;
- Campaigns to promote marine conservation and clean ups though public education and promotion of ethical consumerism;
- Easy access to recycling and other responsible waste disposal alternatives;
- Increased infrastructure to capture plastic items at source;
- Research and development propositions at the material-design level;
- Technological innovations to keep post-consumer plastics in a circular economy loop;
- Regulation, including bans on certain products where appropriate and economic incentives for many different actors in the supply, use and disposal chain;
- Commitment of plastics producers and distributors to adopt end-of-life waste management practices; and
- Setting of achievable policy targets relevant to marine plastic pollution.

Researchers will continue to contribute towards refining our understanding of the nature and scale of the problem, and the full potential of a range of solutions. The research community has convened a central group (the Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection – GESAMP), under the auspices of the United Nations, to ensure a coordinated approach to this challenge. This coordination will help researchers interpret the full range of information available relevant to this challenge.

NGO communities, the private sector and a wide range of policy makers should coordinate with other relevant actors in this space and align initiatives accordingly.

Sources of further information

- Interactive plastic tracking tool: plasticadrift.org
- European video case studies: www.marlisco.eu/watch-troubled-waters.en.html
- Key facts about quantities and types of plastics swirling around UK coastal areas: www.sas.org.uk/wp-content/uploads/SAS-Marine-Litter-Report-Med.pdf
- Making recycling more cost-effective: www.preciousplastic.com

Other organisations

- 5Gyres www.5gyres.org
- Adopt a Beach (California) www.coastal.ca.gov/publiced/aab/aab1.html
- Coastwatch Europe www.coastwatch.org
- Ellen MacArthur Foundation www.ellenmacarthurfoundation.org
- International Coastal CleanUp www.oceanconservancy.org/our-work/international-coastal-cleanup
- Keep Britain Tidy www.keepbritaintidy.org
- KIMO www.kimointernational.org
- Marine Conservation Society www.mcsuk.org
- Marine Debris Program (US) marinedebris.noaa.gov
- Monofilament Recovery & Recycling Program (MRRP) (Florida, US) mrrp.myfwc.com
- The Ocean Cleanup www.theoceancleanup.com
- Project Aware (Dive Against Debris) www.projectaware.org/es/project/dive-against-debris
- Surfers Against Sewage www.sas.org.uk
- WRAP www.wrap.org.uk

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About the authors

Dr Erik van Sebille is a Grantham Lecturer in oceanography and climate science. His research investigates the time scales and pathways of the global ocean circulation, focusing on how currents and eddies in the ocean transport heat and nutrients, as well as marine organisms and plastics between different regions of the ocean. Erik won the 2016 Outstanding Young Scientist Award from the Ocean Division of the European Geosciences Union. He is a member of the United Nations GESAMP expert group on Marine Litter. Erik received his PhD in 2009 from Utrecht University. Before starting at Imperial College London, he worked at the University of New South Wales in Australia and the University of Miami in the US.

Dr Charikleia Spathi was recently awarded a PhD in Materials Resources Engineering from Imperial College London. Her expertise lies in the field of waste valorisation. Her work received the Althea-Imperial Prize in 2015. She now works as a Postdoctoral Research Associate at Sheffield Hallam University, focusing on developing more energy-efficient, environmentally-friendly solutions for commercial glass manufacture.

Alyssa Gilbert is the Head of Policy and Translation at the Grantham Institute, where she connects relevant research across the university with policy-makers and businesses. She is also a member of NERC's Strategic Programme Advisory Committee (SPAG). Alyssa worked at specialist energy and climate consultancy Ecofys for over eleven years researching a range of climate change and environmental policy issues. She has had many years of experience working with government at the international level, in the UK and for other national governments. Alyssa has also worked as a researcher for the Deputy Mayor of London and as a journalist on Environmental Policy in Brussels.

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