SYNTHESIS

FROM POLLUTION TO SOLUTION

A GLOBAL ASSESSMENT OF MARINE LITTER AND PLASTIC POLLUTION

For the rationale and background of this assessment, see Annex 1.

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KEY FINDINGS

1 The amount of marine litter and plastic pollution has been growing rapidly. Emissions of plastic waste into aquatic ecosystems are projected to nearly triple by 2040 without meaningful action.

The scale and rapidly increasing volume of marine litter and plastic pollution are putting the health of all the world's oceans and seas at risk. Plastics, including microplastics, are now ubiquitous. They are a marker of the Anthropocene, the current geological era, and are becoming part of the Earth's fossil record. Plastics have given their name to a new marine microbial habitat, the "plastisphere".

Despite current initiatives and efforts, the amount of plastics in the oceans has been estimated to be around 75-199 million tons. Estimates of annual global emissions from land-based sources vary according to the approaches used. Under a business-as-usual scenario and in the absence of necessary interventions, the amount of plastic waste entering aquatic ecosystems could nearly triple from some 9-14 million tons per year in 2016 to a projected 23-37 million tons per year by 2040. Using another approach, the amount is projected to approximately double from an estimated 19-23 million tons per year in 2016 to around 53 million tons per year by 2030.

2 Marine litter and plastics present a serious threat to all marine life, while also influencing the climate.

Plastics are the largest, most harmful and most persistent fraction of marine litter, accounting for at least 85 per cent of total marine waste. They cause lethal and sub-lethal effects in whales, seals, turtles, birds and fish as well as invertebrates such as bivalves, plankton, worms and corals. Their effects include entanglement, starvation, drowning, laceration of internal tissues, smothering and deprivation of oxygen and light, physiological stress, and toxicological harm.

Plastics can also alter global carbon cycling through their effect on plankton and primary production in marine, freshwater and terrestrial systems. Marine ecosystems, especially mangroves, seagrasses, corals and salt marshes, play a major role in sequestering carbon. The more damage we do to oceans and coastal areas, the harder it is for these ecosystems to both offset and remain resilient to climate change.

When plastics break down in the marine environment, they transfer microplastics, synthetic and cellulosic microfibres, toxic chemicals, metals and micropollutants into waters and sediments and eventually into marine food chains.

Microplastics act as vectors for pathogenic organisms harmful to humans, fish and aquaculture stocks. When microplastics are ingested, they can cause changes in gene and protein expression, inflammation, disruption of feeding behaviour, decreases in growth, changes in brain development, and reduced filtration and respiration rates. They can alter the reproductive success and survival of marine organisms and compromise the ability of keystone species and ecological "engineers" to build reefs or bioturbated sediments.

3 Human health and well-being are at risk

Risks to human health and well-being arise from the open burning of plastic waste, ingestion of seafood contaminated with plastics, exposure to pathogenic bacteria transported on plastics, and leaching out of substances of concern to coastal waters. The release of chemicals associated with plastics through leaching into the marine environment is receiving increasing attention, as some of these chemicals are substances of concern or have endocrine disrupting properties.

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Microplastics can enter the human body through inhalation and absorption via the skin and accumulate in organs including the placenta. Human uptake of microplastics via seafood is likely to pose serious threats to coastal and indigenous communities where marine species are the main source of food. The links between exposure to chemicals associated with plastics in the marine environment and human health are unclear. However, some of these chemicals are associated with serious health impacts, especially in women.

Marine plastics have a widespread effect on society and human well-being. They may deter people from visiting beaches and shorelines and enjoying the benefits of physical activity, social interaction, and general improvement of both physical and mental health. Mental health may be affected by the knowledge that charismatic marine animals such as sea turtles, whales, dolphins and many seabirds are at risk. These animals have cultural importance for some communities. Images and descriptions of whales and seabirds with their stomachs full of plastic fragments, which are prevalent in mainstream media, can provoke strong emotional impacts.

4 There are hidden costs for the global economy.

Marine litter and plastic pollution present serious threats to the livelihoods of coastal communities as well as to shipping and port operations. The economic costs of marine plastic pollution with respect to its impacts on tourism, fisheries and aquaculture, together with other costs such as those of clean-ups, are estimated to have been at least United States dollars (US$) 6-19 billion globally in 2018. It is projected that by 2040 plastic leakage into the oceans could represent a US$ 100 billion annual financial risk for businesses if governments require them to cover waste management costs at expected volumes and recyclability. By comparison, the global plastic market in 2020 has been estimated at around US$ 580 billion while the monetary value of losses of marine natural capital is estimated to be as high as US$ 2,500 billion per year.

5 Marine litter and plastics are threat multipliers.

The multiple and cascading risks posed by marine litter and plastics make them threat multipliers. They can act together with other stressors, such as climate change and overexploitation of marine resources, to cause far greater damage than if they occurred in isolation. Habitat alterations in key coastal ecosystems caused by the direct impacts of marine litter and plastics affect local food production and damage coastal structures, leading to wide-reaching and unpredictable consequences including loss of resilience to extreme events and climate change in coastal communities. The risks of marine litter and plastics therefore need to be assessed across the wider cumulative risks.

6 The main sources of marine litter and plastic pollution are land-based.

Approximately 7,000 million of the estimated 9,200 million tons of cumulative plastic production between 1950 and 2017 became plastic waste, three-quarters of which was discarded and placed in landfills, became part of uncontrolled and mismanaged waste streams, or was dumped or abandoned in the environment, including at sea. Microplastics can enter the oceans via the breakdown of larger plastic items, leachates from landfill sites, sludge from wastewater treatment systems, airborne particles (e.g. from wear and tear on tyres and other items containing plastic), run-off from agriculture, shipbreaking, and accidental cargo losses at sea. Extreme events such as floods, storms and tsunamis can deliver significant volumes of debris into the oceans from coastal areas and accumulations of litter on riverbanks, along shorelines and in estuaries. With global cumulative plastic production between 1950 and 2050 predicted to reach 34,000 million tons, it is urgent to reduce global plastic production and flows of plastic waste into the environment.

7 The movement and accumulation of marine litter and plastics occur over decades.

The movement of marine litter and plastics on- and offshore is controlled by ocean tides, currents, waves and winds, with floating plastics accumulating in the ocean gyres and sinking items concentrating in the deep sea, river deltas, mud belts and mangroves. There can be significant time intervals between losses on land and accumulation in offshore waters and deep-sea sediments. More than half the plastics found floating in some gyres were produced in the 1990s and earlier.

There are now a growing number of hotspots in which there is potential for long-term, large-scale risks to ecosystem functioning and human health. Major sources include the Mediterranean Sea, where large volumes of marine litter and plastic accumulate due its enclosed nature, presenting risks to millions of people; the Arctic Ocean because of potential damage to its pristine nature and harm to indigenous peoples and iconic species through ingestion of plastics in marine food chains; and the East and Southeast Asian region, where there are significant volumes of uncontrolled waste in proximity to very large human populations with a high dependency on the oceans.

8 Technological advances and the growth of citizen science activities are improving detection of marine litter and plastic pollution, but consistency of measurements remains a challenge.

There have been significant improvements in regard to effective and affordable global observational and surveying systems, as well as the protocols for detecting and quantifying litter and microplastics in physical and biotic samples. However, concerns remain among scientists about sampling biases in the determination of the absolute volumes of microplastics found in different habitats owing to high variability in physical and chemical characteristics and the need for greater consistency among different sampling and observation platforms and


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instruments. There are currently 15 major operational monitoring programmes linked to marine litter action co-ordination, data collection frameworks, and large-scale data repository and portal initiatives, but the data and information from them are largely unconnected. Alongside these programmes are indicator processes and baseline data collection activities, supported by a growing number of networks, citizen science projects and participatory processes worldwide.

9 Plastic recycling rates are less than 10 per cent and plastics-related greenhouse gas emissions are significant, but some solutions are emerging.

During the past four decades global plastic production has more than quadrupled, with the global plastic market valued at around US$ 580 billion in 2020. At the same time, the estimated global cost of municipal solid waste management is set to increase from US$ 38 billion in 2019 to US$ 61 billion in 2040 under a business-as-usual scenario. The level of greenhouse gas emissions associated with the production, use and disposal of conventional fossil fuel-based plastics is forecast to grow to approximately 2.1 gigatons of carbon dioxide equivalent ($GtCO_2e$) by 2040, or 19 per cent of the global carbon budget. Using another approach, GHG emissions from plastics in 2015 were estimated to be 1.7 $GtCO_2e$ and projected to increase to approximately 6.5 $GtCO_2e$ by 2050, or 15 per cent of the global carbon budget.

A major problem is the low recycling rate of plastics, which is currently less than 10 per cent. Millions of tons of plastic waste are lost to the environment, or sometimes shipped thousands of kilometres to destinations where it is generally burned or dumped. The estimated annual loss in the value of plastic packaging waste during sorting and processing alone is US$ 80-120 billion. Plastics labelled as biodegradable present another problem, as they may take a number of years to degrade in the oceans and, as litter, can present the same risks as conventional plastics to individuals, biodiversity and ecosystem functioning.

A single-solution strategy will be inadequate to reduce the amount of plastics entering the oceans. Multiple synergistic system interventions are needed upstream and downstream of plastic production and use. Such interventions are already emerging. They include circularity policies, phasing out of unnecessary, avoidable and problematic products and polymers, fiscal instruments such as taxes, fees and charges, deposit-refund schemes, extended producer responsibility schemes, tradeable permits, removal of harmful subsidies, green chemistry innovations for safer alternative polymers and additives, initiatives to change consumer attitudes, and "closing the tap" in regard to virgin plastic production through new service models and ecodesign for product reuse.

10 Progress is being made at all levels, with a potential global instrument in sight.

A growing number of global, regional and national activities are helping to mobilize the global community in order to bring an end to marine litter and plastic pollution.

Cities, municipalities and large firms have been reducing waste flows to landfills; regulatory processes are expanding, driven by growing public pressure; and there has been an upsurge in local activism and local government actions including kerbside collections, plastics recycling and community clean-ups. However, the current situation is a mixture of widely varying business practices and national regulatory and voluntary arrangements.

There are already some international commitments to reduce marine litter and plastic pollution, especially from land-based sources, as well as several applicable international agreements and soft law instruments relating to trade in plastics or to reducing impacts on marine life. However, none of the international policies agreed since 2000 includes a global, binding, specific and measurable target limiting plastic pollution. This has led many governments, as well as business and civil society, to call for a global instrument on marine litter and plastic pollution.

INTRODUCTION

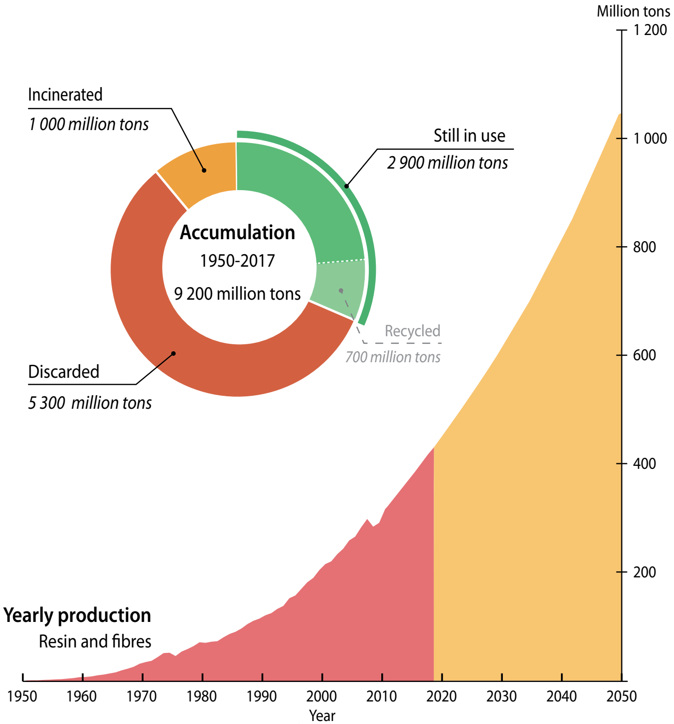
Marine litter and plastic pollution are accumulating in the world's oceans at an unprecedented rate. The volume of plastics currently in the oceans has been estimated at between 75 million and 199 million tons[1] (Jang et al. 2015; Ocean Conservancy and McKinsey Centre for Business and Environment 2015; Law 2017; IRP 2019; Lebreton et al. 2019; Borrelle et al. 2020; Lau et al. 2020; The Pew Charitable Trusts and SYSTEMIQ 2020). Plastic waste can be found in sea floor sediments, on beaches, and in many other locations globally. Consequently, plastic pollution is becoming part of the Earth's fossil record and is a characteristic of the present geological era, the Anthropocene. A new marine microbial habitat has been designated the "plastisphere" (Amaral-Zettler et al. 2020).

Marine litter enters the oceans directly and indirectly through pathways including land, rivers and the atmosphere. The main sources of plastics in the ocean include uncontrolled waste streams on land, treated and untreated wastewater outflows, wear and tear on plastic products including textiles and vehicle tyres, run-off from land, leakages from plastics used in agriculture, and direct inputs from maritime industries (Geyer 2020).

Marine life and ecosystems are adversely impacted by litter, including plastics and microplastics. In addition, microplastics in these ecosystems present potential risks to human health, for example through seafood consumption. Depending on their type, size and location, marine litter and plastics can cause lethal and sub-lethal effects on marine life through entanglement, smothering, ingestion, and exposure to the chemicals associated with plastics (Aliani and Molcard 2003; Rochman et al. 2016; Alomar and Deudero 2017; Franco-Trecu et al. 2017; Lusher et al. 2017a; Reinert et al. 2017; Anbumani and Kakkar 2018; Fossi et al. 2018; Thiel et al. 2018; Alimba and Faggio 2019; Bucci et al. 2019; Windsor et al. 2019; Woods et al. 2019). There is evidence that floating plastics can transport chemicals and pathogenic bacteria into coastal areas where they present risks to both ecosystems and human health (Rech et al. 2016; Turner 2016; Besseling et al. 2019; Guo and Wang 2019; Yu et al. 2019).

Plastic fragments are the form of plastic waste most commonly found on shorelines. Microplastics, which are mainly created through the fragmentation of macroplastics, are ubiquitous in the marine environment. Microplastics can alter the reproductive success and survival of marine organisms and compromise the ability of keystone species and ecological "engineers", such as corals and worms, to build reefs or bioturbate sediments (Sussarellu et al. 2016; Green et al. 2017; Beckwith and Fuentes 2018; Bradney et al. 2019; Green et al. 2019; Reichert et al. 2019; Renzi et al. 2019; Saliu et al. 2019; Maes et al. 2020). There is evidence that plastics can alter carbon cycling, hence contributing to climate change, through their effect on primary production in marine, freshwater and terrestrial systems (Green et al. 2017; Beckwith and Fuentes 2018; Bradney et al. 2019; Green et al. 2019; Reichert et al. 2019; Renzi et al. 2019; Saliu et al. 2019).

Effectively tackling the problems of marine litter and plastic pollution requires a wide range of actions directed at the generation, disposal, management and leakage of waste from land- and sea-based sources, as well as measures related to plastics' overall production volumes and chemical make-up. Plastics are among the most versatile materials ever produced. They have changed the lives of billions of people and the global economy. However, the environmental and social costs of their use are significant. The annual economic costs of marine plastic pollution with respect to its impacts on tourism, fisheries and aquaculture, together with other costs including clean-up activities, are estimated to be at least United States dollars (US$) 6-19 billion per year globally (Deloitte 2019). It is projected that by 2040 the expected mass of plastic leakage into the ocean could result in a US$ 100 billion annual financial risk for businesses if governments require them to cover waste management costs at expected volumes and recyclability (The Pew Charitable Trusts and SYSTEMIQ 2020). Global cumulative production of plastics since 1950 is forecast to grow from 9.2 million tons in 2017 to 34 million tons by 2050 (Geyer 2020) (Figure I). Therefore, it is urgent to "turn off the tap" in regard to the production of virgin plastics, reduce the volumes of uncontrolled or mismanaged waste entering the oceans, and increase the level of plastic waste recycling, currently estimated at less than 10 per cent (Andrades et al. 2018; Boucher and Billard 2019; Geyer 2020). Plastic manufacturing produces significant greenhouse gas (GHG) emissions (Shen et al. 2020), which contributes to their effects on the climate (The Pew Charitable Trusts and SYSTEMIQ 2020).



Sources: UNEP 2021, adapted from Jambeck et al. 2018; PlasticsEurope 2019; Geyer 2020.
Illustrated by GRID-Arendal

Figure 1: Global plastic production, accumulation and future trends

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[1] In this report tons refers to metric tons.

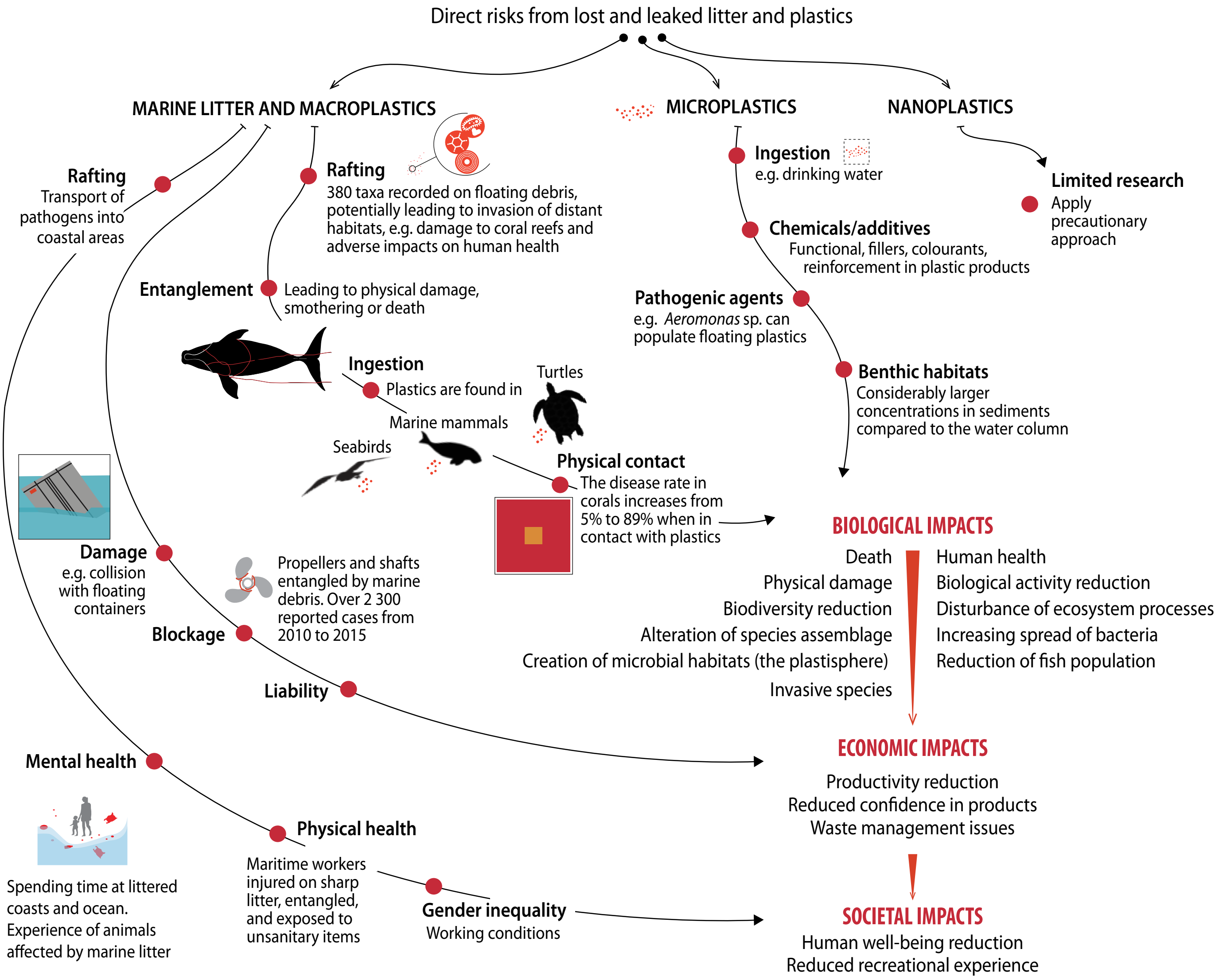
ENVIRONMENTAL, HEALTH, SOCIAL AND ECONOMIC IMPACTS

Environmental impacts

Marine litter and plastic pollution are harmful to the healthy functioning of oceans. Since the publication of the 2016 UNEP report Marine Plastic Debris and Microplastics – Global Lessons and Research to Inspire Action and Guide Policy Change, substantial new research has shown the extensive damage that marine litter, especially plastics and their breakdown products, causes to marine life and ecosystem functioning as well as potential risks to human health (Figure 2).

The lethal and sub-lethal effects of plastics include ingestion by whales, seals, turtles, birds and fish, potentially leading to starvation and lacerations in internal systems, and the smothering of coral reefs, causing deprivation of oxygen and light; drowning of turtles, birds and mammals due to entanglement in abandoned fishing gear and plastic packaging; and physiological stress and toxicological harm arising from the ingestion of microplastics by plankton, shellfish, fish and marine worms, all of which are critical to ecosystem functioning (Browne et al. 2008; Carson et al. 2013; Wright et al. 2013a, b; Adimey et al. 2014; Hämer et al. 2014; Rochman et al. 2014; Au et al. 2015; Brennecke et al. 2015; Desforges et al. 2015; Wilcox et al. 2015; Holland et al. 2016; Green et al. 2017; Lusher et al. 2017a; Anbumani and Kakkar 2018; Duncan et al. 2018a; Duncan et al. 2018b; Hallanger and Gabrielsen 2018; McNeish et al. 2018; Reynolds and Ryan 2018; Arias et al. 2019; Battisti et al. 2019; Donohue et al. 2019; Nelms et al. 2019a Sun et al. 2019; Landrigan et al. 2020; Vethaak and Legler 2021).

When plastics break down in the marine environment, microplastics, toxic chemicals and metals are transferred into open surface waters and eventually into sediments, where they can be assimilated into marine food chains (Arthur et al. 2009; Ashton et al. 2010; Mattsson et al. 2015; Haward 2018; Karlsson et al. 2018; UNEP 2018a). The effects and causal mechanisms of harm from microplastics are unevenly studied in the field. However, under



Sources: UNEP 2021.

Illustrated by GRID-Arendal

Figure 2: Direct risks and impacts of marine litter and plastics

laboratory conditions they have been shown to cause changes in gene and protein expression, inflammation, disruption of feeding behaviour, decreases in growth and reproductive success, changes in brain development, reduced filtration and respiration rates, and a range of diseases leading to decreased survival (von Moos 2012; Au et al. 2015; Cole et al. 2015; Nobre et al. 2015; Paul-Pont et al. 2016; Sussarellu et al. 2016; Cui et al. 2017; Lusher et al. 2017a; Anbumani and Kakkar 2018; Arthur et al. 2019; Bradney et al. 2019; Green et al. 2019; SAPEA 2019; European Union 2019a; Jacob et al. 2020; Lindeque et al. 2020; Peng, L. et al. 2020; de Ruijter et al. 2020; Silva et al. 2020; Xu et al. 2020).

Microplastics can also be responsible for physical changes in the environment, for example on beaches where they may cause temperature fluctuations which can affect the sex determination in sea turtle eggs buried in the sand (Carson et al. 2011; Beckwith and Fuentes 2018).

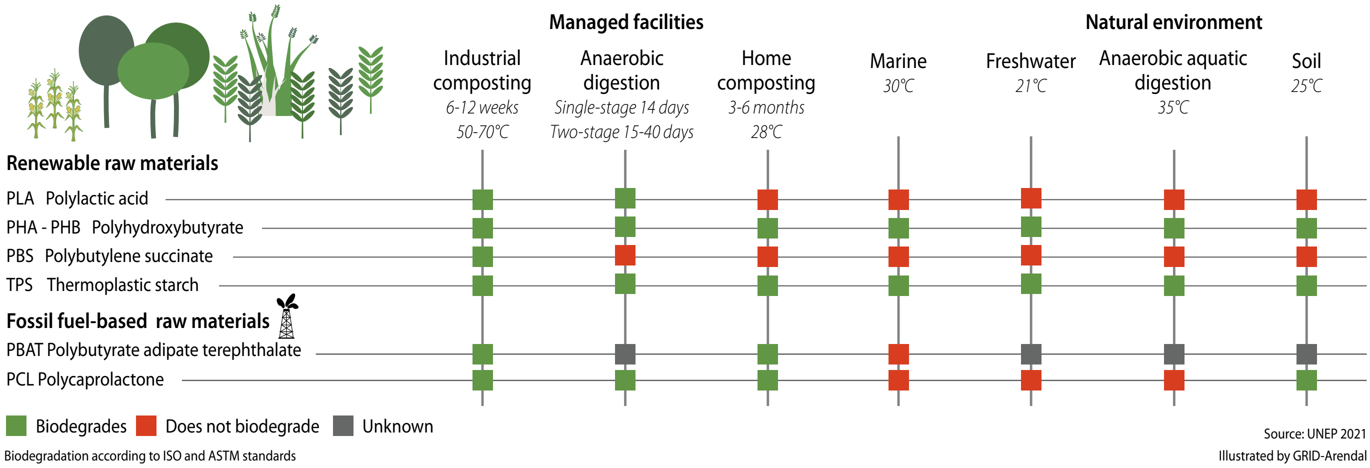
Microplastics can act as vectors of pathogenic organisms which are harmful to both marine life and human health (such as Vibrio sp., the bacterial family responsible for cholera, and Aeromonas salmonicida, responsible for causing furunculosis and septicaemia in salmonid fishes) and create conditions for plasmid transfer in bacterial assemblages and for enhanced horizontal transfer of gene encoding for antimicrobial resistance (Kirstein et al. 2016; Viršek et al. 2017; Huang et al. 2019; Arias-Andres et al. 2018; Yang et al. 2019; Goel et al. 2021). The ever-decreasing size of microplastics creates large surface areas where microbial "plastisphere" communities and biofilms may develop.

The release of chemicals associated with plastics through leaching into the marine environment or post-ingestion into the tissues of marine life is receiving growing attention, as some of these chemicals, such as bisphenol A, have endocrine disrupting properties while others are considered substances of concern (e.g. UNEP/IPCP 2016; Hermabessiere et al. 2017; Hong et al. 2017a; M'Rabat et al. 2018; Groh et al. 2019; Guo and Wang 2019; Flaws et al. 2020; Thaysen et al. 2020; UNEP 2020d). Microplastics have been demonstrated to sorb persistent organic pollutants (POPs) as well as trace metals (Anbumani and Kakkar 2018; Camacho et al. 2019; Guo and Wang 2019; Fred-Ahmadu et al. 2020; Pozo et al. 2020). Natural sediments and organic matter also have the capacity to adsorb hydrophobic organic chemicals (Koelmans et al. 2016; Prata et al. 2020a).

The extent of contamination and rate of transfer of chemicals from microplastics into marine waters and the tissues of marine organisms are highly dependent on chemical and physical conditions such as the nature and strength of the chemical bonds between the chemicals and polymers, pH, temperature, pressure, biofouling, the presence of surfactants, the volumes of different polymer types ingested, and gut concentrations and residence time (Gouin et al. 2011; Koelmans et al. 2014; Bakir et al. 2016; Herzke et al. 2016; Koelmans et al. 2016; Rummel et al. 2016; Anbumani and Kakkar 2018; De Frond et al. 2019; Koelmans et al. 2019; UNEP 2020d).

Other plastic breakdown products in the oceans include cellulosic and synthetic microfibres and nanoplastics (Boucher and Friot 2017; Belzagui et al. 2019) that come directly from waste streams, agricultural run-off, wastewater discharged from treatment plants which may contain microfibres from washing of synthetic textiles, and plastic particles created in the oceans by fragmentation and physical abrasion. Although synthetic microfibres and nanoplastics accumulate in sedimentary sinks where they can persist for many years, most fibres in the oceans and in sediments are composed of natural polymers which eventually degrade (Obbard et al. 2014; Remy et al. 2015; Woodall et al. 2015; Taylor et al. 2016; Welden and Cowie 2016; Avio et al. 2017; Bagaev et al. 2017; Dris et al. 2017; Miller et al. 2017; Sanchez-Vidal et al. 2018; Windsor et al. 2018; Henry et al. 2019; Primpke et al. 2019; Song et al. 2018; Ronda et al. 2019; Stanton et al. 2019b; Zambrano et al. 2019; Harris 2020; Suaria et al. 2020).

A rapidly expanding area of research concerns biodegradable and bio-sourced plastics, their biological and environmental impacts, and industry labelling and certification. The results of field studies show that when these plastics are outside industrial or controlled composting conditions, some can persist for many years once they are in marine environments without showing any signs of biodegradation (O'Brine and Thompson 2010; Alvarez-Zeferino et al. 2015; Green et al. 2015; Narancic et al. 2018; UNEP 2018a; Napper and Thompson 2019) (Figure 3). In the environment, therefore, these types of plastics



	Managed facilities			Natural environment			
	Industrial composting *6-12 weeks* *50-70℃*	Anaerobic digestion *Single-stage 14 days* *Two-stage 15-40 days*	Home composting *3-6 months* *28℃*	Marine *30℃*	Freshwater *21℃*	Anaerobic aquatic digestion *35℃*	Soil *25℃*
Renewable raw materials							
PLA Polylactic acid	🟩	🟩	🟥	🟥	🟥	🟥	🟥
PHA - PHB Polyhydroxybutyrate	🟩	🟩	🟩	🟩	🟩	🟩	🟩
PBS Polybutylene succinate	🟩	🟥	🟥	🟥	🟥	🟥	🟥
TPS Thermoplastic starch	🟩	🟩	🟩	🟩	🟩	🟩	🟩
Fossil fuel-based raw materials							
PBAT Polybutyrate adipate terephthalate	🟩	⬛	🟩	🟥	⬛	⬛	⬛
PCL Polycaprolactone	🟩	🟩	🟩	🟥	🟥	🟥	🟩

🟩 Biodegrades 🟥 Does not biodegrade ⬛ Unknown

Biodegradation according to ISO and ASTM standards

Source: UNEP 2021
Illustrated by GRID-Arendal

Figure 3: Bio-based plastics and their biodegradation

are likely to pose the same risks as conventional plastics (Alvarez-Zeferino et al. 2015; Green 2016; Green et al. 2016; Green et al. 2017; Green et al. 2019; Napper and Thompson 2019; Zimmermann et al. 2020; UNEP 2021).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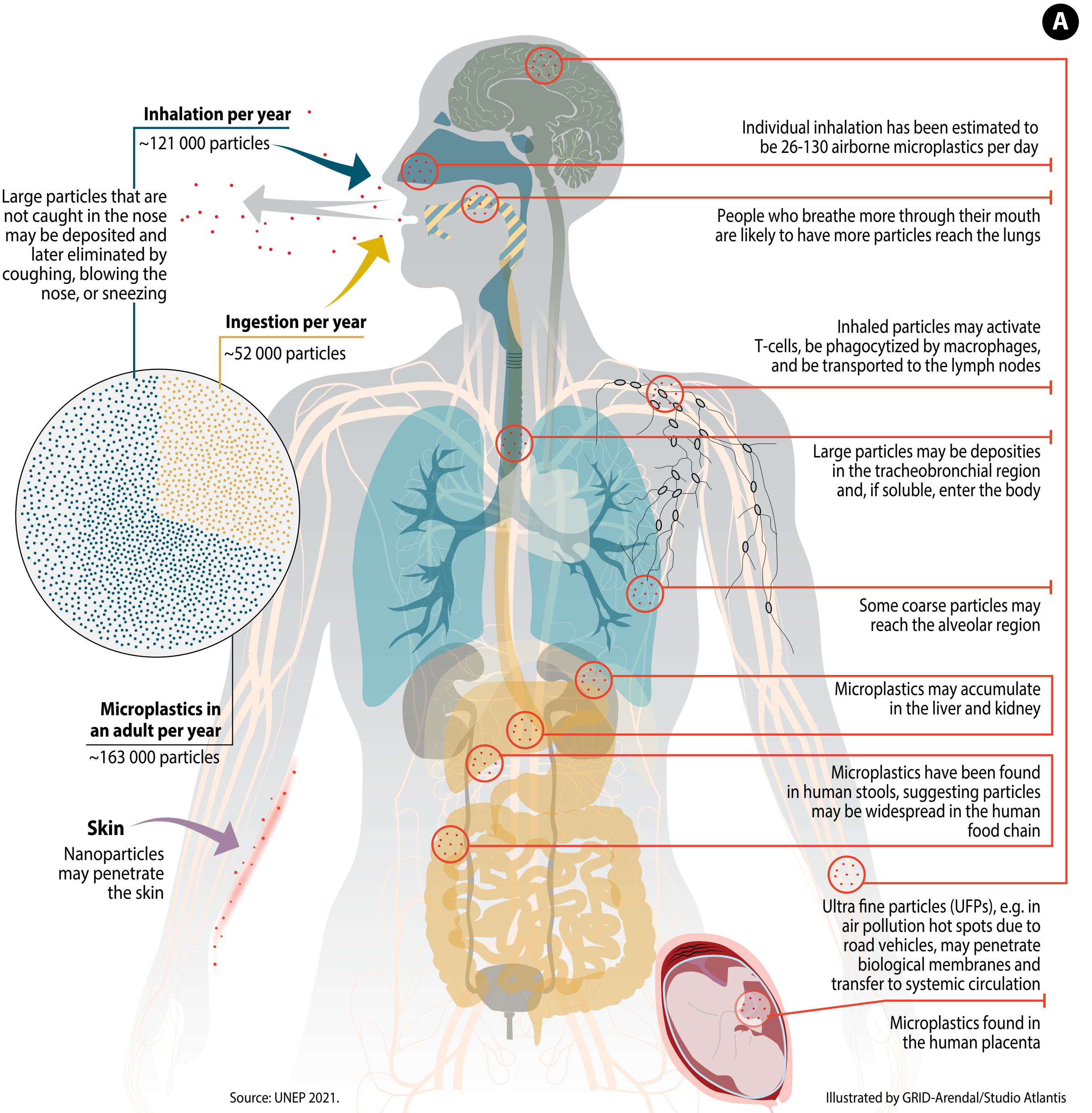
Human health impacts

The human health impacts of marine litter and plastic pollution arise mainly from inadequate waste handling, especially on land; ingestion of contaminated seafoods; and exposure to pathogenic bacteria and substances of concern transported into coastal waters by floating plastics (Landrigan et al. 2020). Exposure to toxic fumes and carcinogenic chemicals associated with the burning of plastics in open pits and poor incineration is considered a serious health risk, with known gendered effects among waste workers in the informal sector (van den Bergh and Botzen 2015; ILO 2017; UNEP 2017; ILO 2019; UNESCAP 2019).



Inhalation per year
~121 000 particles

Large particles that are not caught in the nose may be deposited and later eliminated by coughing, blowing the nose, or sneezing

Ingestion per year
~52 000 particles

Microplastics in an adult per year
~163 000 particles

Skin
Nanoparticles may penetrate the skin

Individual inhalation has been estimated to be 26-130 airborne microplastics per day

People who breathe more through their mouth are likely to have more particles reach the lungs

Inhaled particles may activate T-cells, be phagocytized by macrophages, and be transported to the lymph nodes

Large particles may be deposities in the tracheobronchial region and, if soluble, enter the body

Some coarse particles may reach the alveolar region

Microplastics may accumulate in the liver and kidney

Microplastics have been found in human stools, suggesting particles may be widespread in the human food chain

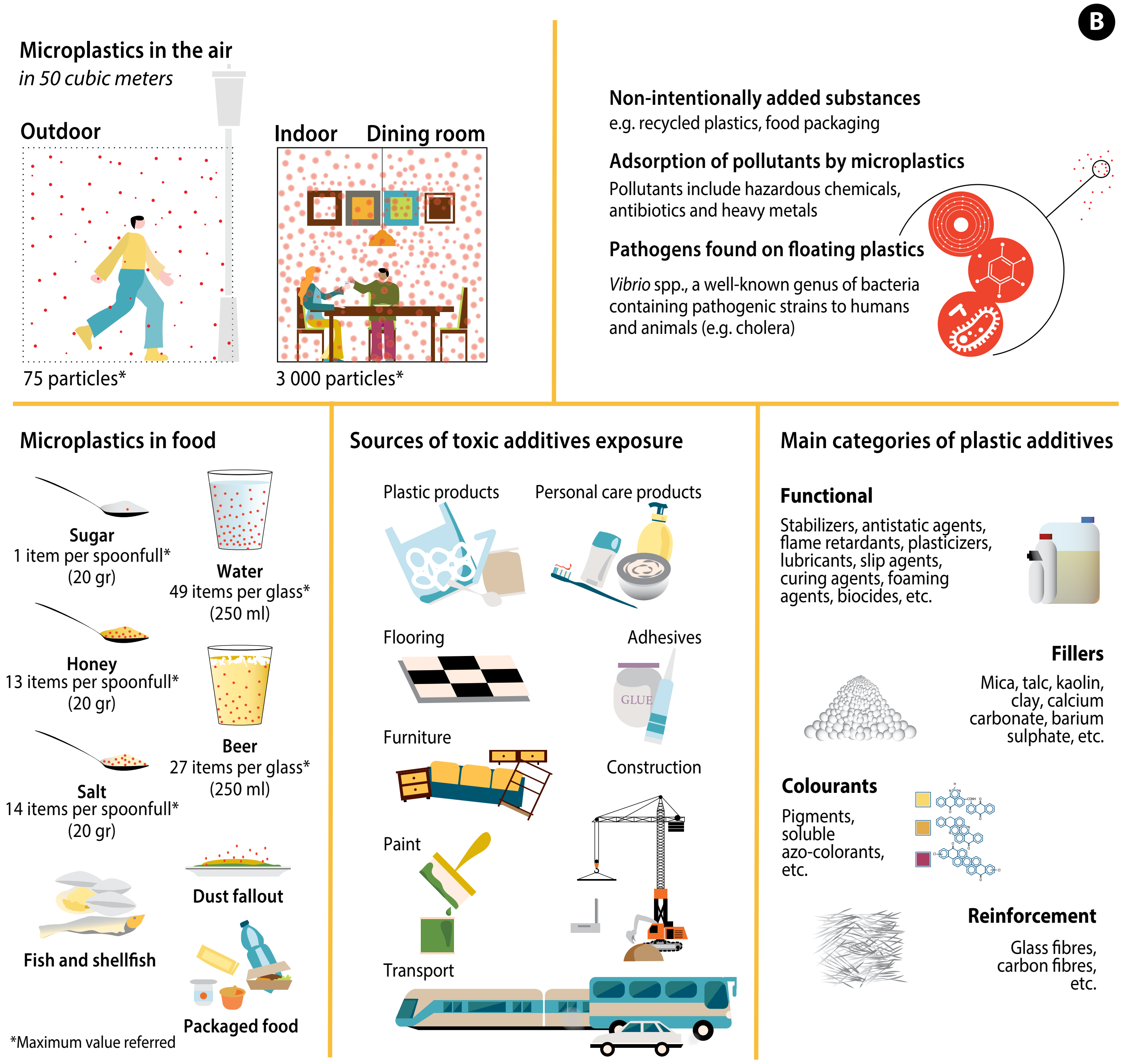
Ultra fine particles (UFPs), e.g. in air pollution hot spots due to road vehicles, may penetrate biological membranes and transfer to systemic circulation

Microplastics found in the human placenta

Source: UNEP 2021.

Illustrated by GRID-Arendal/Studio Atlantis

Figure 4-A: Human exposure to microplastic and nanoplastic particles



Source: UNEP 2021

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Figure 4-B: Human exposure to plastic particles and associated chemicals


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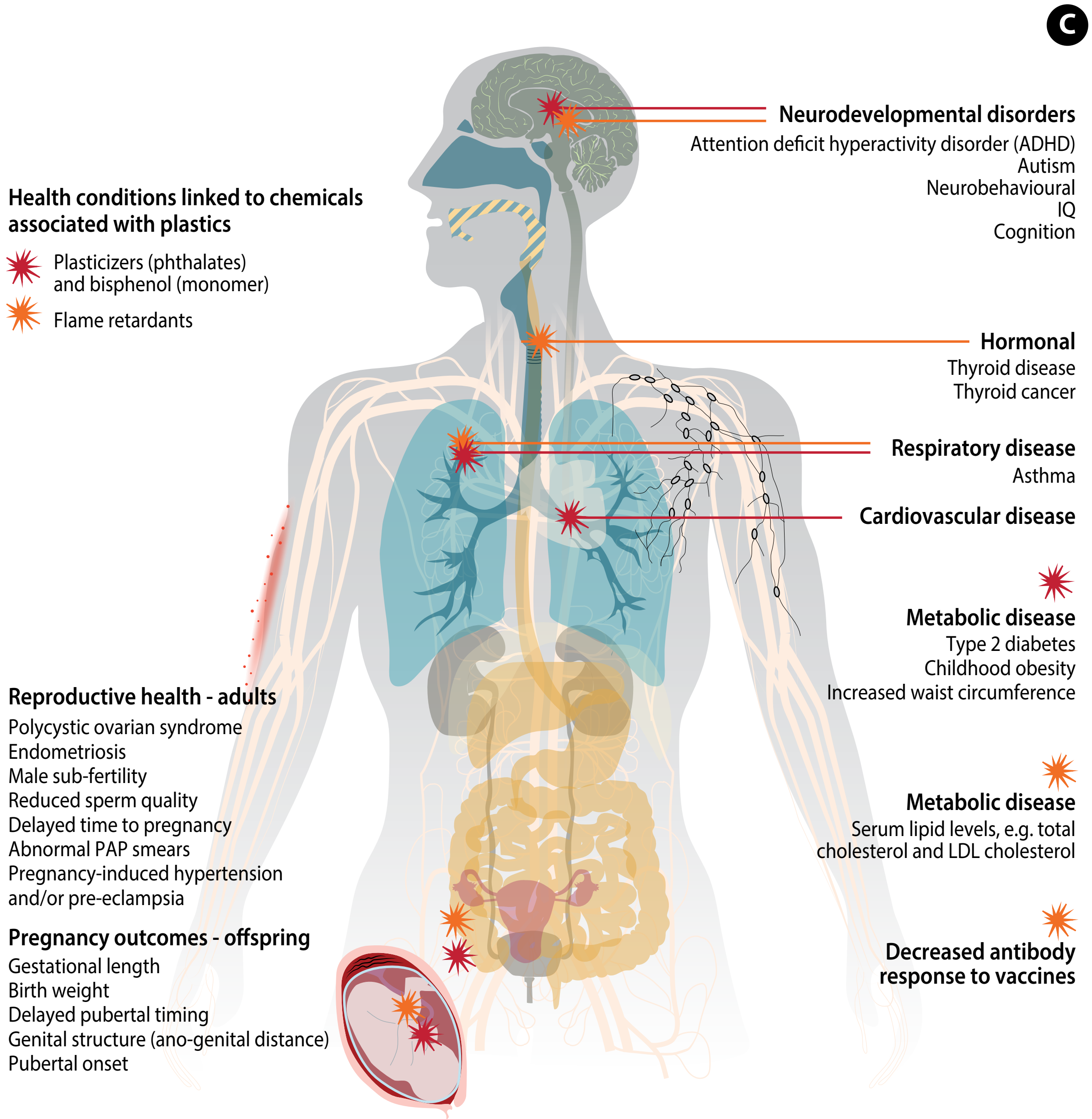
More generally, microplastics and nanoplastics pose potential risks to human health. Evidence from clinical studies indicates that they can enter the human body via ingestion, inhalation and absorption through the skin and accumulate in organs including the placenta (Wright and Kelly 2017; Cox et al. 2019; Koelmans et al. 2019; WHO 2019, Landrigan et al. 2020) (Figure 4). Although a link to seafoods has not been fully demonstrated, and overall exposure levels from marine plastics as well as health impacts remain uncertain, there is substantial evidence that chemicals associated with plastics such as methylmercury, plasticizers and flame retardants can enter the human body along these pathways and are associated with serious health impacts, especially in women and in certain coastal indigenous communities where marine species are the main source of food (Dehaut et al. 2016; Wright and Kelly 2017; Koelmans et al. 2019; WHO 2019; Adyel 2020; Kögel et al. 2020; Prata et al. 2020; Landrigan et al. 2020; Tekman et al. 2020).



Source: UNEP 2021.

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Figure 4-C: Human health impacts of exposure to plastic-associated chemicals

Social and economic impacts

Studies of the effects of marine litter and plastics on shipping, port operations, fisheries and aquaculture emphasize that they result in damage to ships from collisions and entanglement in propellers and present navigational hazards (Jeffrey et al. 2016; Hong et al. 2017b); disrupt port operations (IMarEST 2019); reduce the efficiency and productivity of commercial fisheries and aquaculture operations through physical entanglement and damage (Richardson et al. 2019; Deshpande et al. 2020); pose direct risks to fish stocks and aquaculture (Lusher et al. 2017a); and can have profound visual and aesthetic impacts, for example on tourists and other people who visit beaches (Munari et al. 2015; Pasternak et al. 2017; UNEP 2017; Petrolia et al. 2019; Williams and Rangel-Buitrago 2019).

The estimated US$ 6-19 billion annual costs of marine plastic pollution, based on impacts including those on tourism, fisheries and aquaculture and the expense of clean-ups (Deloitte 2019), represent only a small percentage of the global plastic market, valued at more than US$ 579 billion in 2020 (Statista 2021a). Owing to insufficient available research, these costs do not include impacts on human health or marine ecosystems. A lack of comprehensive figures for all economic costs related to marine litter and plastic pollution is a common problem (Newman et al. 2015; UNEP 2017; Gattringer 2018).

Four types of economic costs generally need to be addressed: actual expenditures required to prevent or recover from damage caused by marine litter and plastic pollution; losses of output or revenues; losses of plastics as valuable material withdrawn from production; and welfare costs, including human health impacts and losses of ecosystem services. The majority of published studies have focused on economic damage or direct losses at regional, national and local levels and the price adjustments needed to internalize the social costs of plastics (Hall 2000; Ferreira et al. 2007; MacFadyen 2009; Mouat et al. 2010; McIlgorm et al. 2011; Jang et al. 2014; Oosterhuis et al. 2014; Newman et al. 2015; Krelling et al. 2017; Gattringer 2018; Leggett et al. 2018; Dalberg Advisors, WWF Mediterranean Marine Initiative 2019; Qiang et al. 2020).

Some studies have examined the non-market and intangible environmental and social costs of marine litter and plastics. For example, in a coastal fishing community on Thailand's Andaman Sea "increased garbage in the ocean" was ranked as the highest environmental stressor (Lynn et al. 2017). Other indirect measurements include avoided costs related to the informal waste picking sector; for example, in 2016 informal waste pickers were estimated to be responsible for collecting 55-64 per cent of plastics for recycling globally (Lau et al. 2020). For many countries, however, economic data on the costs of damage caused by marine litter including plastics do not exist (Janssen et al. 2014; Jambeck et al. 2018).

At a regional scale more studies are looking at this issue. In the Mediterranean Sea, acknowledged to be one of the seas most affected by marine litter and plastic pollution (Eriksen et al. 2014; Cózar et al. 2015; UNEP/MAP 2015; Suaria et al. 2016; UNEP/MAP 2017; Campanale et al. 2019; Constantino et al. 2019; Dalberg Advisors, WWF Mediterranean Marine Initiative 2019; Fossi et al. 2020), annual losses of some US$ 696 million are sustained in the three major sectors (fisheries and aquaculture, shipping, and tourism) combined, with around US$ 150 million per year lost in the fishing sector alone (Dalberg Advisors, WWF Mediterranean Marine Initiative 2019). These figures do not include income losses or damage to ecosystem services caused by plastics.

In the Asia-Pacific Economic Cooperation (APEC) countries the estimated annual economic costs of marine litter in 2008 were US$ 1.26 billion (McIlgorm et al. 2008; McIlgorm et al. 2011), rising to US$ 10.8 billion in 2015 (Asia-Pacific Economic Cooperation 2017; McIlgorm et al. 2020). These figures for the Asia-Pacific region reflect increasing global plastic production. Statista (2021b) estimates that cumulative global production was 8.3 million tons in 2017 and will grow to 34 million tons in 2030. The world's maritime industries are also growing: as of 2019 the total value of annual seagoing shipping trade alone was reported to be more than US$ 14 trillion (International Chamber of Shipping 2021).

Estimating the costs of damage to ecosystem functioning is challenging. Beaumont et al. (2019) used De Groot et al. (2012) and Costanza et al. (2014), despite concerns about accuracy, to derive an estimate of the reduction in the value of marine natural capital in the oceans because of plastics of between US$ 500-2,500 billion per year. Analysing the loss of benefits that marine ecosystem services provide is an appropriate method for estimating non-market, intangible costs of marine plastics; before this method can be applied globally, however, a comprehensive, interdisciplinary analysis will be needed to take account of the interdependencies between economic, social and ecological systems (Gattringer 2018).

Compared to the size of the global plastic market in 2020, estimated at around US$ 580 billion (Statista 2021a), the World Trade Organization reports that the value of global merchandise exports alone in 2020 was around US$ 17.65 trillion (compared to US$ 19,014 trillion in 2019 and 19.55 trillion in 2018, before the COVID-19 pandemic began) (WTO 2021). The value of trade flows of plastics from raw materials to finished goods have recently been calculated to amount to about US$ 1 trillion (UNCTAD 2020). However, the price of virgin plastics does not reflect the full environmental, economic and social costs of their disposal. Instead, these costs are passed on, for example to coastal communities and the maritime sectors. The Pew Charitable Trusts and SYSTEMIQ (2020), using a business-as-usual scenario for 2040, projected that 4 billion people are likely to be without organized waste collection services by that year and that businesses could face a US$ 100 billion annual financial risk if governments require them to cover waste management costs at expected volumes and recyclability.

Figures such as these are indicative of widespread market failures and underline the need for a systems-wide, solutions-based approach that focuses on the challenges – technological (e.g. the scalability of different recycling technologies and substitute materials), economic (e.g. the relative cost of different solutions), environmental (e.g. GHG emissions associated with different solutions) and social (e.g. equity and social justice for waste pickers) – that need to be met to prevent mismanaged plastic waste and the subsequent costs of environmental pollution entering the marine environment (Lau et al. 2020).

There is growing awareness worldwide that the marine environment is under threat from plastic pollution as well as from overfishing (Lotze et al. 2018; Hartley et al. 2018b; Wyles et al. 2019). There is evidence that people experience well-being as a consequence of knowing that marine animals will continue to exist even if they have never seen these animals in person (Börger et al. 2014; Jobstvogt et al. 2014; Aanesen et al. 2015; Eagle et al. 2016). This is especially true in the case of charismatic marine animals such as turtles, whales, dolphins and seabirds, which often have cultural as well as emotional importance for individuals. Images and descriptions of whales or seabirds whose stomachs are full of plastic fragments, prevalent in mainstream media (e.g. Reuters 2017), can have a strong detrimental impact in this regard (Lotze et al. 2018).

Failure to visit beaches and shorelines because the presence of marine litter and plastics can have health implications means there is a lack of opportunity to enjoy benefits such as physical activity, social interaction (e.g. strengthening of family bonds), and general improvement of both physical and mental health (Ashbullby et al. 2013; Papathanasopoulou et al. 2016; Kiessling et al. 2017; Hartley et al. 2018a; White et al. 2020). On the other hand, the need to rid these areas of litter can stimulate citizen initiatives including beach clean-up activities (Brouwer et al. 2017; Hartley et al. 2018b).

Handling marine litter and plastics can have different impacts on particular groups (e.g. women, children, waste workers, and coastal communities where plastic waste is collected and burned) (ILO 2017; UNEP 2017; ILO 2019; UNESCAP 2019). It has been proposed that the social costs of marine plastics should be included when the ways in which plastics are produced, used, reused and reprocessed are considered (van den Bergh and Botzen 2015). Marine litter and plastic pollution can infringe on a number of human rights. They affect people in vulnerable conditions disproportionally, including those living in poverty, indigenous and coastal communities, and children, potentially aggravating existing environmental injustices (United Nations General Assembly 2021).

RISK FRAMEWORK FOR MARINE LITTER AND PLASTIC POLLUTION

The multiple and cascading risks that marine litter and plastics present with regard to ecosystems and society mean they may act as threat multipliers (UNDRR 2019). Plastics, in particular, are stressors that can be understood to act together with other stressors (e.g. climate change and overexploitation of marine resources), resulting in far greater damage than when they are considered in isolation (Backhaus and Wagner 2019). For example, GHG emissions from the production, use and disposal of fossil fuel-based plastics account for 19 per cent of the total emissions budget allowable in 2040 if the world is to avoid significant climate change (The Pew Charitable Trusts and SYSTEMIQ 2020). Habitat alterations in key coastal ecosystems caused by the direct impacts of marine litter, including plastics and microplastics, not only affect local food production and coastal protection, but may lead to wide-reaching and unpredictable secondary societal consequences through impairment of ecosystem resilience and the potential of coastal communities to withstand extreme weather events and climate change (Galloway et al. 2017; Carvalho-Souza et al. 2018; Woods et al. 2019; GESAMP 2020a). These issues underscore the urgent need for a coherent approach to managing the risks of marine litter and plastic pollution (Hardesty and Wilcox 2017; Royer et al. 2018; Adam et al. 2019; Backhaus and Wagner 2019; UNDRR 2019; GESAMP 2020a; Peng, L. et al. 2020; Shen et al. 2020).

The Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection (GESAMP) (2020a) has suggested that no single approach to risk is suitable to assess the wide range of potential hazards and exposure routes associated with marine litter and to take into account all the possible environmental, social and economic consequences. Therefore, setting out a risk framework and adopting a tiered approach for addressing marine litter and plastic pollution has been proposed (Koelmans et al. 2017; GESAMP 2020a). This approach reflects growing experience with the development of tools for assessing hazard and risk in a wide range of applications. The relevant factors to be considered vary. They include existing knowledge and urgency. Social considerations and potential public or environmental health risks are to be taken into account. The objective of such a risk framework is to deliver “fit for purpose” risk framework to ensure that non-priorities are set aside and to inform risk management (Koelmans et al. 2017). Risk matrices can provide a way to highlight the existence of knowledge gaps and assist with problem formulation.

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SOURCES AND PATHWAYS OF MARINE LITTER, INCLUDING PLASTICS AND MICROPLASTICS

Land- and sea-based sources

The volume of plastics in the oceans, which has been calculated by a number of researchers , is estimated to be between 75 and 199 million metric tons (Jang et al. 2015; Ocean Conservancy and McKinsey Centre for Business and Environment 2015; Law 2017; International Research Panel 2019; Lebreton et al. 2019; Borrelle et al. 2020; Lau et al. 2020; The Pew Charitable Trusts and SYSTEMIQ 2020). Between 1950 and 2017 roughly 7,000 million tons out of the 9,200 million tons of global cumulative plastic production became plastic waste, of which three-quarters was discarded and ended up in landfills, dumps, uncontrolled or mismanaged waste streams, or the natural environment, including the oceans (Geyer 2020).

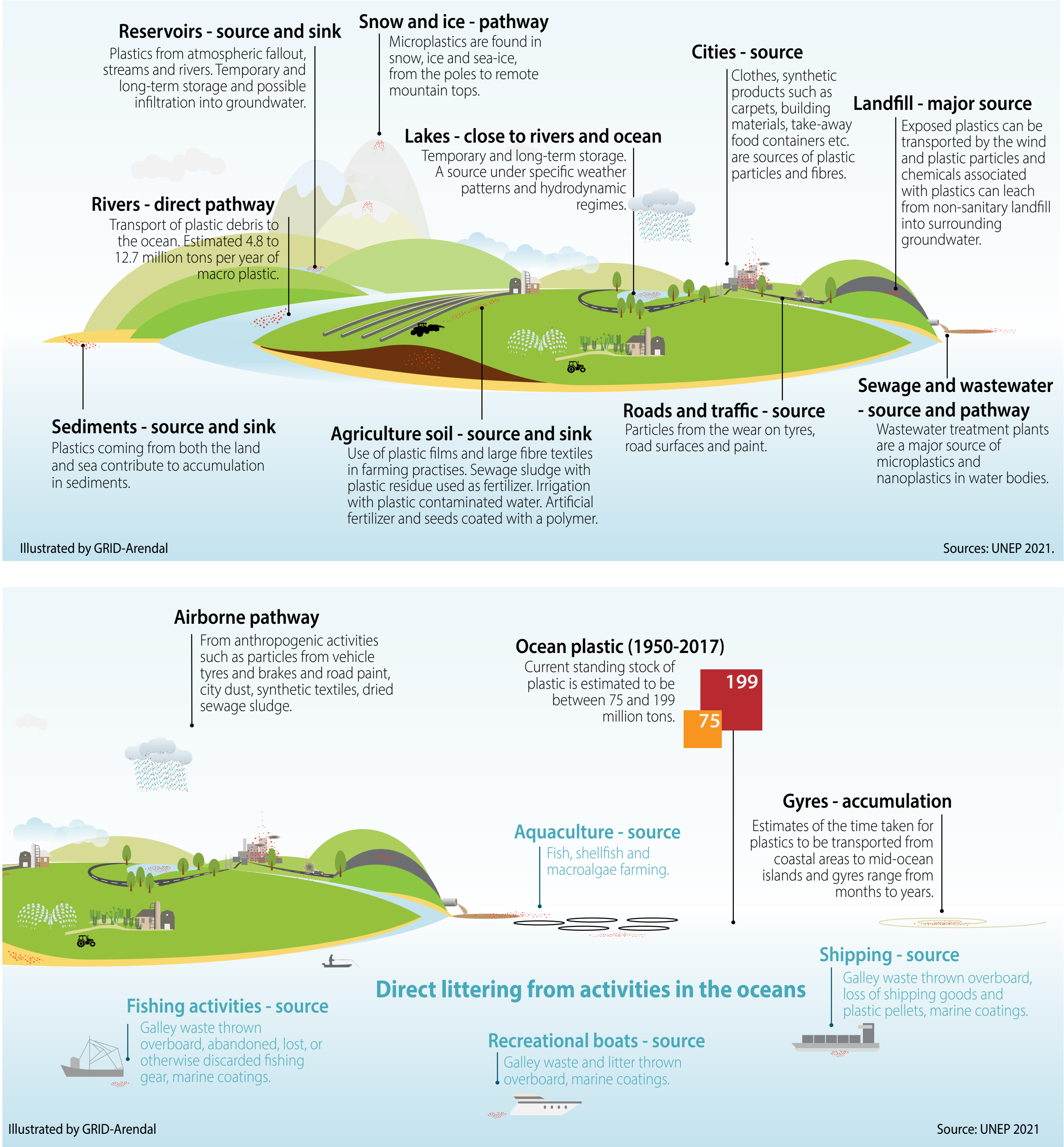
Marine litter comes mainly from land-based sources, including agriculture, wastewater treatment plants, construction, transportation, unnecessary, avoidable and problematic plastic products and polymers, and a wide variety of personal and health care products; approximately 60 per cent of macroplastic leakage is from uncontrolled waste streams (UNEP 2018c; IRP 2019; van Truong et al. 2019; Geyer 2020; The Pew Charitable Trusts and SYSTEMIQ 2020). Sea-based sources include fisheries and aquaculture, shipping and offshore operations, and ship-based tourism (GESAMP 2015; IMarEST 2019; Ryan et al. 2019; FAO 2020; GESAMP 2020b) (Figure 5). Personal protective equipment, widely used during the COVID-19 pandemic, has added significantly to current volumes of plastic waste (Adyel 2020). Estimated annual global emissions of plastic waste from land-based sources vary according to the approaches used. The volume of plastic waste entering aquatic ecosystems is projected to more than double from an estimated 19-23 million tons per year in 2016 to as much as 53 million tons per year by 2030 (Borrelle et al. 2020). Emissions entering aquatic ecosystems are projected to nearly triple from 9-14 million tons per year in 2016 to 23-37 million tons per year by 2040 (Lau et al. 2020). Using another appraoch, Meijer et al. (2021) estimate that 0.8-2.7 million tons of plastic waste per year enter the oceans from riverine systems (Table 1).

Microplastics are present in leachates from landfill sites, sludge from wastewater treatment plants, and agricultural run-off (Mason et al. 2016; Mahon et al. 2017; Li et al. 2018; Cowger et al. 2019; He et al. 2019; Sun et al. 2019) (Figure 6). Agricultural soils can become sinks of microplastics through the intentional application of sewage sludge and effluents, and plastic-coated seeds and agrochemicals (e.g. controlled release fertilizers) (Nizzetto et al. 2016a,b; Piehl et al. 2018; Accinnelli et al. 2019; Corradini et al. 2019; Wang et al. 2019a,b).

Abandoned, lost or otherwise discarded fishing gear from fisheries and aquaculture installations is the largest single category by volume of debris found on beaches (Welden and Cowie 2017; European Commission 2018a) and at sea (Veiga et

Table 1: Estimates of annual global emissions of plastic waste from land-based sources

Estimated plastic waste emissions (million tons per year)	Source-to-sea aspect	Projected plastic waste emissions (million tons per year)	Approach used
19-23	Entered aquatic ecosystems in 2016	53 by 2030	Integrating expected population growth, annual waste generation per capita, the proportion of plastic in waste; incorporating an increase in plastic materials associated with predicted production increases, and the proportion of inadequately managed waste by country (Borelle et al. 2020)
9-14	Entered aquatic ecosystems in 2016	23-37 by 2040 (equivalent to 50 kg of plastic per metre of coastline worldwide)	Modelled stocks and flows of municipal solid waste and four sources of microplastics through the global plastic system using five scenarios (2016-2040) and assuming no effective action is taken (Lau et al. 2020)
0.8-2.7	Entered the oceans from global riverine systems in 2015	--	Based on >1,000 rivers, calibrated using field observations (Meijer et al. 2021)



Illustrated by GRID-Arendal

Sources: UNEP 2021.

Illustrated by GRID-Arendal

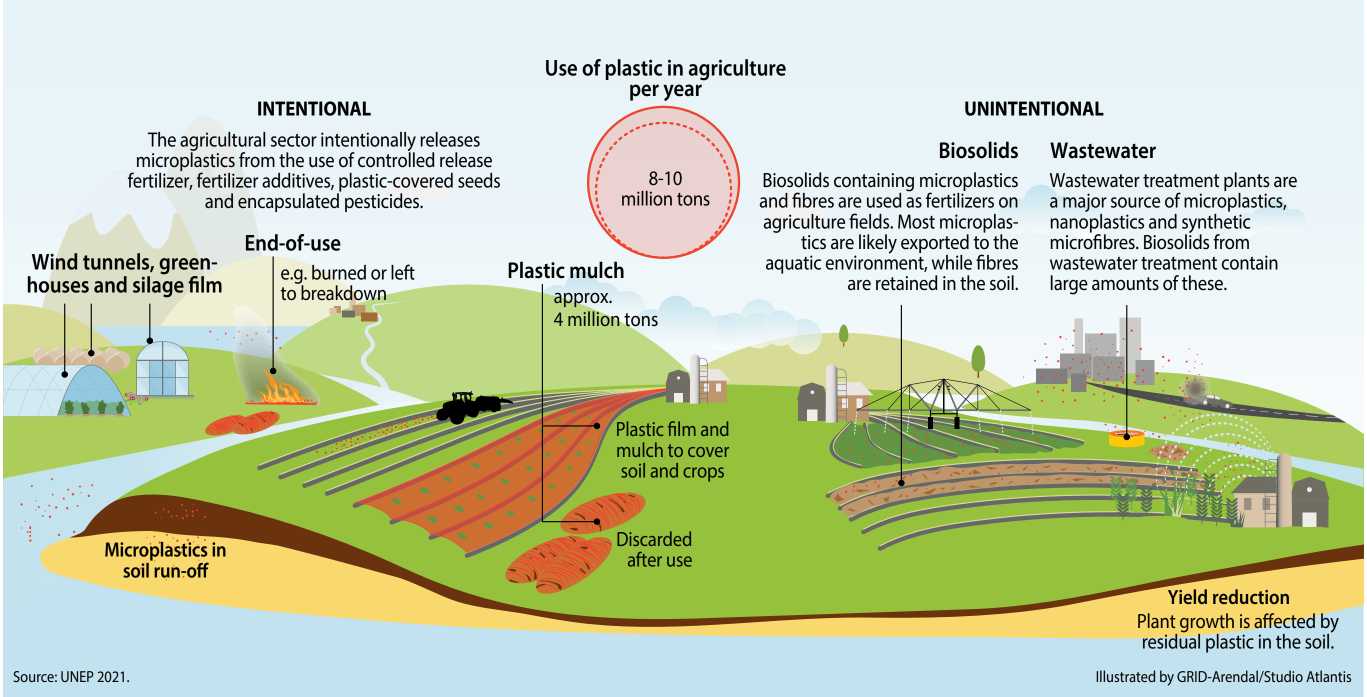
Source: UNEP 2021

Figure 5: Major pathways of human generated plastic waste in the marine environment

al. 2016; Vlachogianni et al. 2017; Lebreton 2018; Stelfox et al. 2016; Fleet et al. 2021). Nets, ropes, cages and nylon lines can have a disproportionate effect by damaging key habitat-forming marine organisms such as corals and seagrasses through tissue abrasion and smothering (Ballesteros et al. 2018), sometimes significantly reducing their extent and functioning (Richards and Beger 2011; Carvalho-Souza et al. 2018).

A major source of plastic contamination in some coastal areas is shipbreaking (Science for Environment Policy 2016). In a study in a shipyard in India the authors found thousands of small plastic fragments, averaging 81 mg per kg of sediment, which they reported to be the direct result of shipbreaking (Reddy et al. 2006). It is thought that 1 to 2 per cent of the 6 million boats maintained in Europe (i.e. at least 80,000) reach end-of-life each year, but that only around 2,000 are adequately dismantled (European Commission 2017) (Figure 7).

Marine litter and plastic pollution enter the oceans along multiple pathways such as run-off over land, riverine flows, wastewater and greywater flows, and airborne transport, as well as directly from maritime operations (Figures 6 and 7) (Alomar et al. 2016; Nizzetto et al. 2016a; Nizzetto et al. 2016b; Auta et al. 2017; Lebreton et al. 2017; Alimi et al. 2018; Horton and Dixon 2018; Best 2019; Akarsu et al. 2020; Chen et al. 2020; Birch et al. 2020; Peng, L. et al. 2020). Extreme events such



Use of plastic in agriculture per year

INTENTIONAL

The agricultural sector intentionally releases microplastics from the use of controlled release fertilizer, fertilizer additives, plastic-covered seeds and encapsulated pesticides.

UNINTENTIONAL

Biosolids

Biosolids containing microplastics and fibres are used as fertilizers on agriculture fields. Most microplastics are likely exported to the aquatic environment, while fibres are retained in the soil.

Wastewater

Wastewater treatment plants are a major source of microplastics, nanoplastics and synthetic microfibres. Biosolids from wastewater treatment contain large amounts of these.

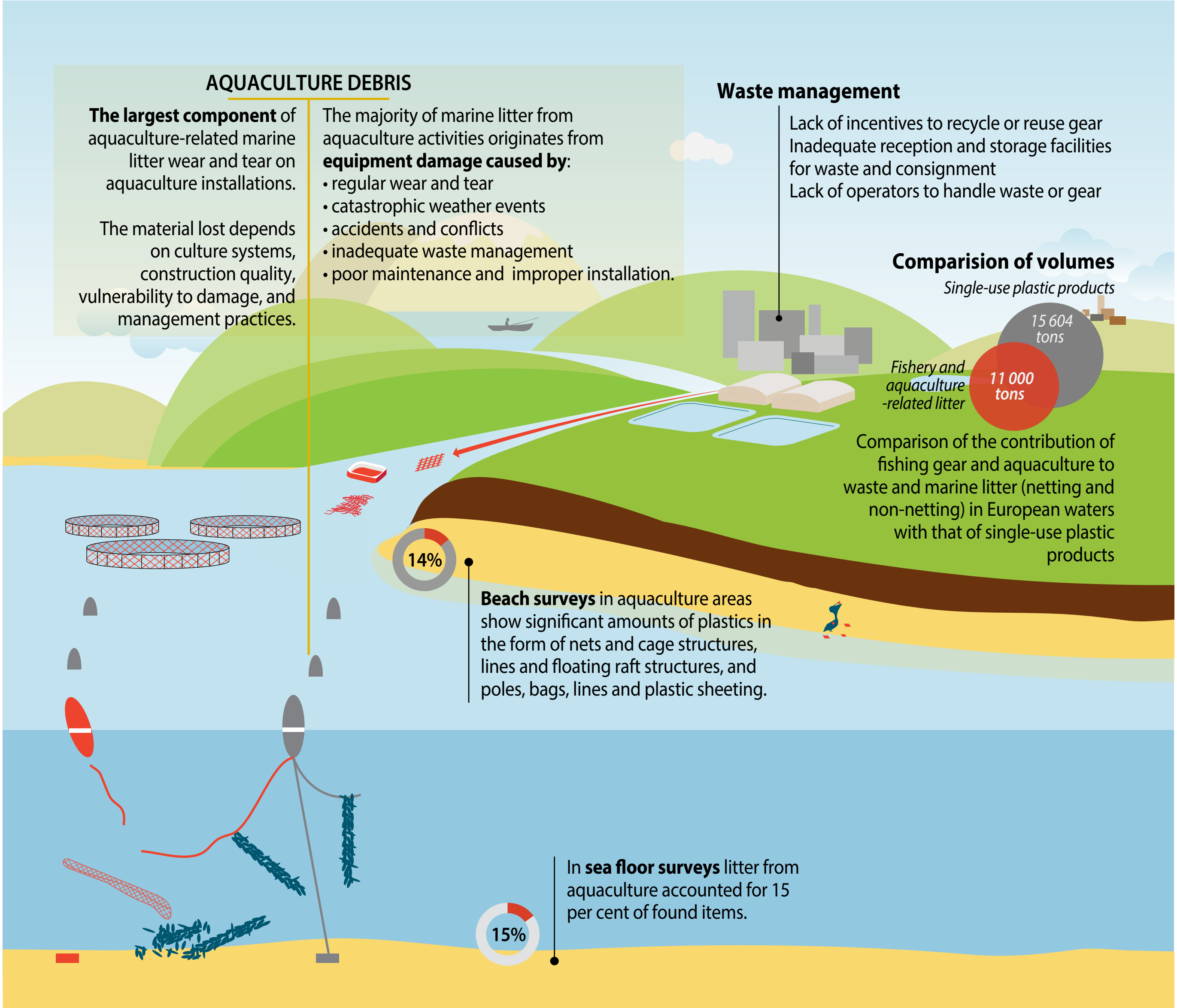
Yield reduction

Plant growth is affected by residual plastic in the soil.

Source: UNEP 2021.

Illustrated by GRID-Arendal/Studio Atlantis

Figure 6: Agricultural practices contributing to marine litter and plastic pollution



AQUACULTURE DEBRIS

The largest component of aquaculture-related marine litter wear and tear on aquaculture installations.

The material lost depends on culture systems, construction quality, vulnerability to damage, and management practices.

The majority of marine litter from aquaculture activities originates from **equipment damage caused by**:

- regular wear and tear
- catastrophic weather events
- accidents and conflicts
- inadequate waste management
- poor maintenance and improper installation.

Waste management

Lack of incentives to recycle or reuse gear

Inadequate reception and storage facilities for waste and consignment

Lack of operators to handle waste or gear

Comparision of volumes

Comparison of the contribution of fishing gear and aquaculture to waste and marine litter (netting and non-netting) in European waters with that of single-use plastic products

Beach surveys in aquaculture areas show significant amounts of plastics in the form of nets and cage structures, lines and floating raft structures, and poles, bags, lines and plastic sheeting.

In **sea floor surveys** litter from aquaculture accounted for 15 per cent of found items.

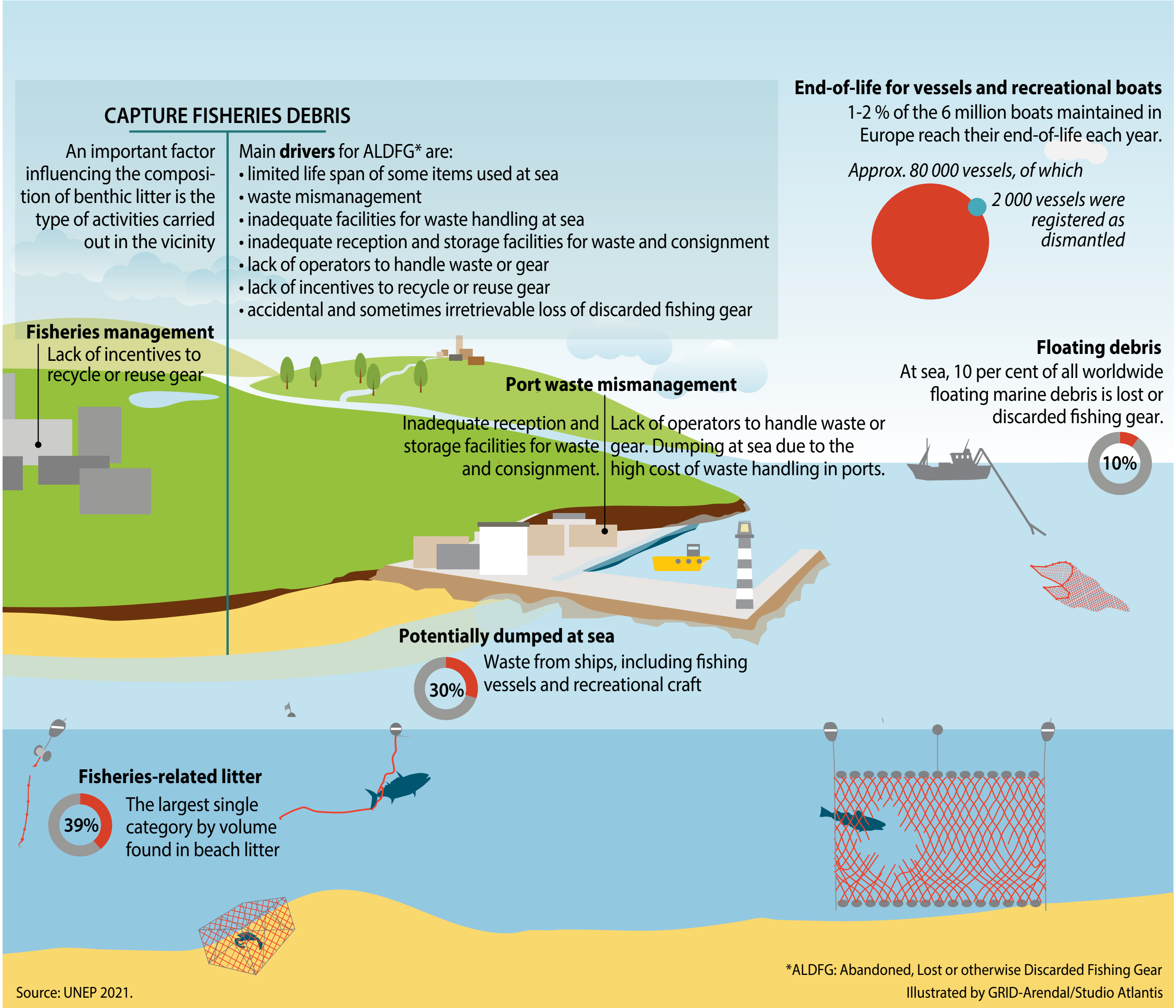
Figure 7: Fisheries and aquaculture practices contributing to marine litter and plastic pollution

as floods, storms and tsunamis can also deliver significant volumes of debris from coastal areas and accumulations of litter from riverbanks, estuaries and shorelines (Werbowski et al. 2021) and from damage to coastal infrastructure into the oceans (NOAA 2015; Lusher 2017b; Murray et al. 2018; GESAMP 2019). Surveys of seafloor debris have helped to determine the most likely pathways taken by litter and microplastics by using brand labels to identify their age and most likely sources (Cau 2019).

Once litter and microplastics have entered the marine environment, their movement is controlled by ocean tides, currents, waves and winds. In coastal areas tides interact with shoreline characteristics and move litter on- and offshore, depending on its chemical composition, surface charge, density, size and shape (Mattsson et al. 2015; Chubarenko et al. 2016; Fazey and Ryan 2016; Kooi et al. 2016; Pedrotti et al. 2016; Zhang 2017; Alimi et al. 2018; Chubarenko et al. 2018; Dussud et al. 2018a,b; Lebreton et al. 2018; Castro-Jiménez et al. 2019; Lebreton et al. 2019; Napper and Thompson 2019; Onink et al. 2019; Peng, G. et al. 2020; van Sebille et al. 2020; Harris et al. 2021) (Figure 8).

Floating marine litter, including plastics, becomes caught up in gyres and eddies; it can sink or float, depending on fragmentation rates, density, wind and waves, and interactions with marine organisms, and they accumulate in large offshore gyres (Cózar et al. 2014; Law et al. 2014; Duhec et al. 2015; Díaz-Torres et al. 2017; Imhof et al. 2017; Lavers and Bond 2017; Collins and Hermes 2019; Lebreton et al. 2019; van der Mheen et al. 2019; Wichmann et al. 2019; Dunlop et al. 2020). Nearly half the total mass of plastics in sub-tropical offshore waters consists of macroplastic fragments older than 15 years (Lebreton et al. 2019). Shore deposition is an important process, as abrasion and fragmentation of plastics causes microplastics to form and toxic chemical and heavy metals from plastics to be released (Nakashima et al. 2016; Lavers and Bond 2017).

While the pathways and fate of plastics are broadly understood, the absolute volumes, especially of microplastics, are still not well known due to poor sampling coverage and lack of standardized sampling protocols (Galgani et al. 2021; Harris et al. 2021). Current global estimates have thus been determined



Source: UNEP 2021.

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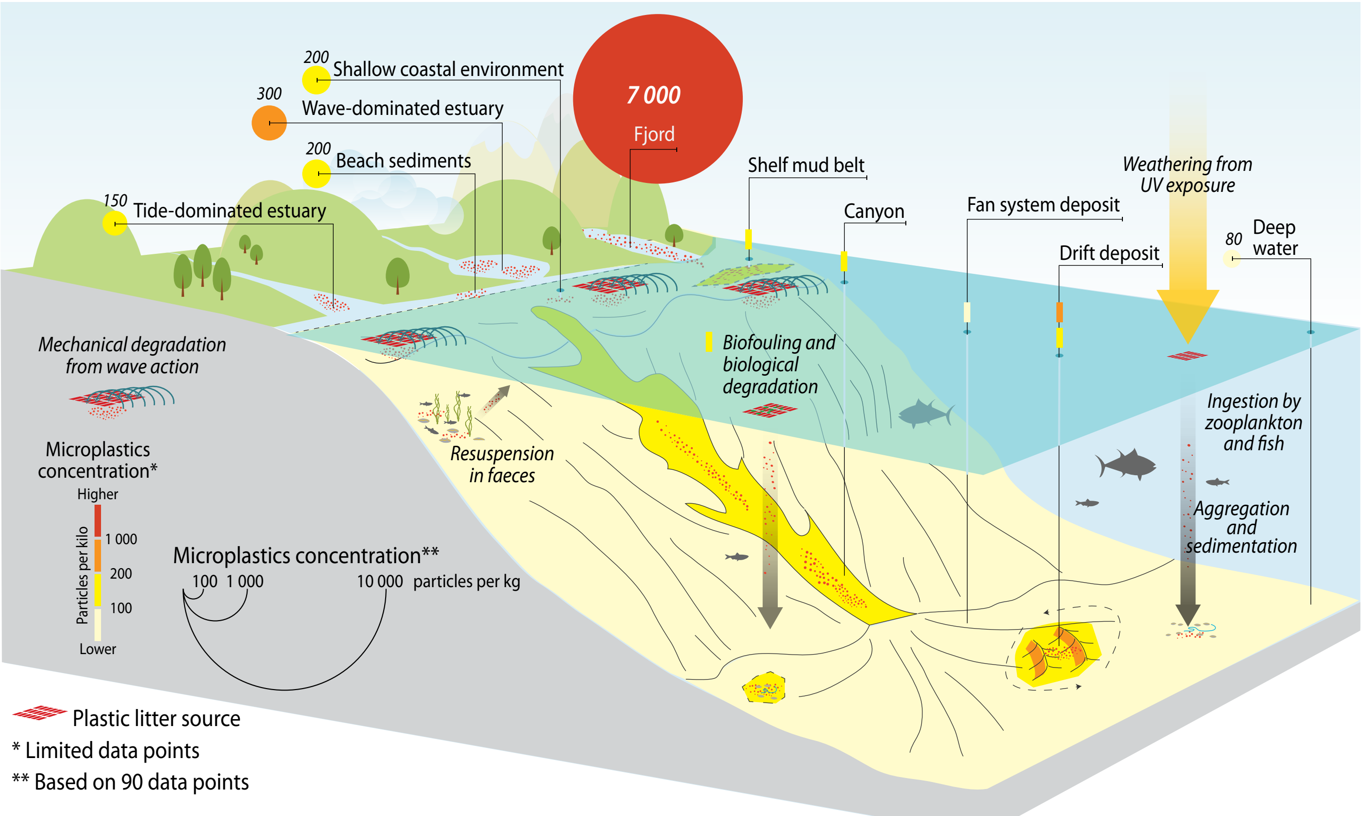
Figure 7 *(continued)*



Source: UNEP 2021.

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Figure 8: Natural processes affecting the distribution and fate of microplastics


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primarily through modelling, based on proxies such as population densities, rather than on direct measurements (Galgani et al. 2021). There can also be significant time intervals between losses on land and accumulation in offshore waters and deep-sea sediments; for example, plastics found floating in some offshore gyres were produced several decades previously (Kedzierski et al. 2018; Lebreton et al. 2019; van Sebille et al. 2020).

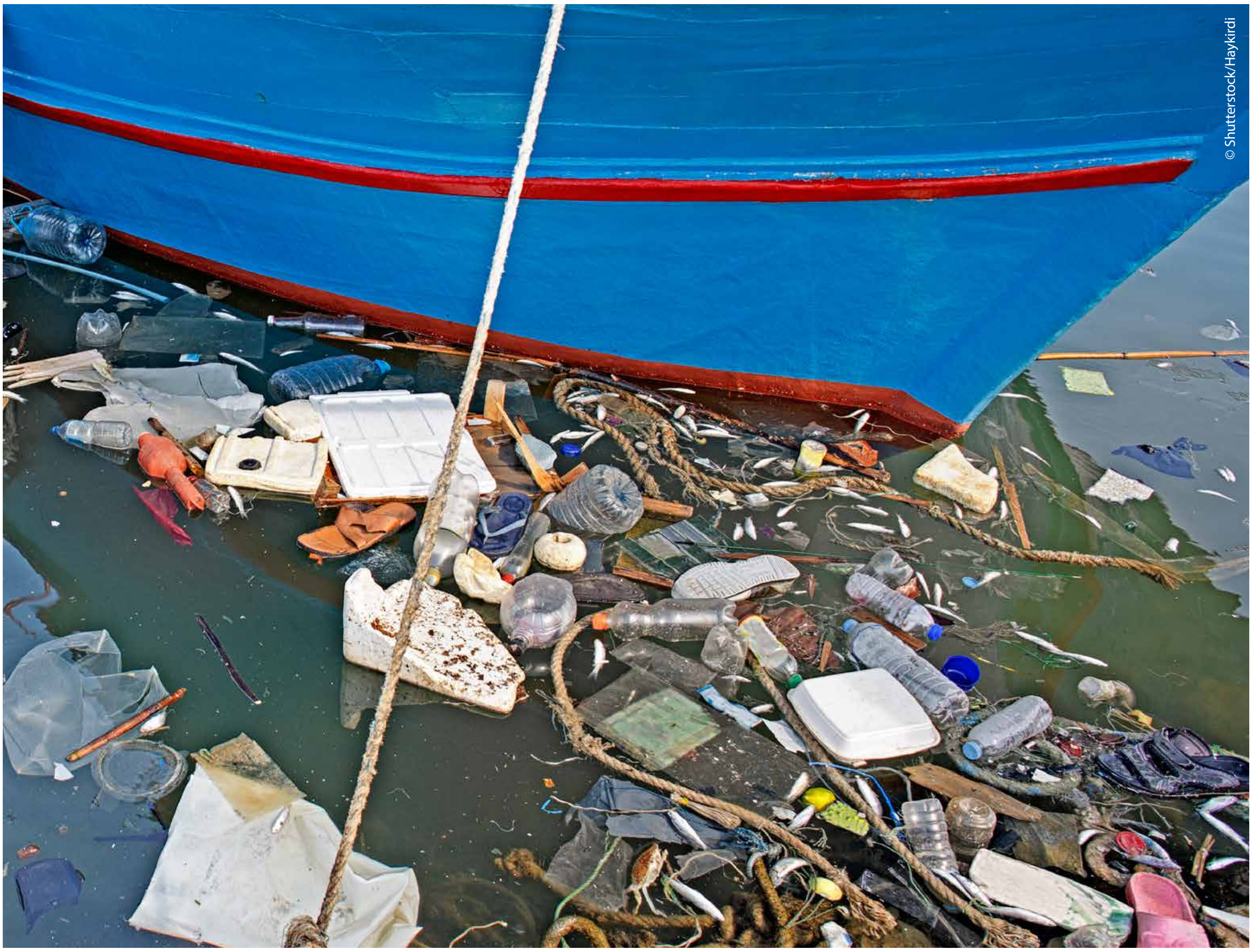
Regional hotspots for marine litter and microplastics have been identified where there is a potential for large-scale risks to ecosystem functioning and human health. Examples include the Mediterranean Sea, where large volumes are accumulating because of its enclosed nature and the large quantities of waste flowing into it every year, posing risks to millions of people living around the coastline (Dalberg Advisors, WWF Mediterranean Marine Initiative 2019; Boucher and Bilard 2020); the Arctic Ocean because of potential damage to its pristine nature and harm to iconic species and indigenous peoples through the ingestion of plastics in the marine food chain and seafood (Sundet et al. 2016; Hallanger and Gabrielsen 2018; Kanhai et al. 2018; Donohue et al. 2019; Kanhai et al. 2019); and the East Asia and ASEAN region because of significant volumes of uncontrolled waste and an extensive coastline in proximity to very large populations that are highly dependent on the marine environment for survival (Cai et al. 2017; Lyons et al 2019; Purba et al. 2019; Onda and Sharief 2021).

MEASURING AND MONITORING MARINE LITTER, INCLUDING PLASTICS AND MICROPLASTICS

There have been many improvements and modifications to laboratory protocols, monitoring methods and surveying techniques for marine litter and plastic pollution, in riverine, atmospheric, shoreline, coastal and offshore environments (González-Fernández and Hanke 2017; Carvalho-Souza et al. 2018; Chiba et al. 2018; Galgani et al. 2018; GESAMP 2019; Karlsson et al. 2019; van Calcar and van Emmerik 2019; Enyoh et al. 2019; GESAMP 2019; Prata et al. 2019; Schulz et al. 2019; Stanton et al. 2019a; Forrest et al. 2020; UNEP 2020a,b,c). Significant efforts have also been made to develop effective sampling of microplastics, although the consistency between different techniques has been questioned (Besley et al. 2017; Costa and Duarte 2017; Lusher et al. 2017b; Blettler et al. 2018; da Costa 2018; Borja and Elliott 2019; van Emmerik and Schwartz 2019; Koelmans et al. 2020; Ryan et al. 2020). Biotic sampling has also improved with the development of different methods to investigate dietary exposure to microplastics (Nelms et al. 2019b; Maes et al. 2020; Markic et al. 2020).

The main challenge now is the intercalibration of all techniques in order to improve reliability and repeatability of results, so that data can be used for modelling and predicting the distribution and quantities of marine litter and plastic pollution in different habitats (Braun et al. 2018; GESAMP 2019; Maximenko et al. 2019). Scientists still have widespread concerns about sampling biases among the different field and laboratory techniques for identifying and determining the volume of microplastics in the environment. Intrinsic difficulties exist due to the high variability in the size, shape, colour, and degree of degradation of plastics. Without significant improvements in quality assurance and standardization of sampling and analytical techniques, it will remain difficult to harmonize published results and to demonstrate their reliability and repeatability.

Digital technologies, satellites, aircraft and drones, combined with shipborne sensors, samplers and autonomous platforms (e.g. floats, gliders, benthic landers and crawlers), ships-of-opportunity and modelling are opening up the possibility for affordable global monitoring programmes to track and determine the densities of marine litter, notably plastics, from rivers, coastal areas out into the open ocean and into the hadal depths (Tekman et al. 2017; Zambianchi et al. 2017; Centurioni et al. 2019; Franceschini et al. 2019; Maximenko et al. 2019; Moltmann et al. 2019; Koelmans et al. 2019; Lebreton et al.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MARINE LITTER ACTION COORDINATION		GEOGRAPHICAL RANGE	ACTIVITIES	APPLICATION AREA	INCLUDES CITIZEN SCIENCE
GPML	*Global Partnership on Marine Litter*	*Worldwide*	⬛⬛🟩🟧	🟨🟨🟦🟫🟥🟩	yes
GEOSS	*Global Earth Observation System of Systems' Platform*	*Worldwide*	⬛⬛🟩🟧	🟨🟨🟦🟫🟥🟩	-
-	*Living Atlas of the World*	*Worldwide*	⬛🟦🟩⬛	🟨🟨🟦🟫🟥🟩	yes
ODIS	*IOC Ocean data and information system*	*Worldwide*	⬛⬛🟩🟧	🟨🟨🟦🟫🟥🟩	-
ODP	*Ocean Data Platform*	*Worldwide*	⬛⬛🟩🟧	🟨🟨🟦🟫🟥🟩	yes
MDMAP	*NOAA Marine Debris Monitoring and Assessment Project*	*US west coast, Worldwide*	⬛⬛🟩🟧	🟨⬛⬛⬛⬛⬛	yes
MSFD	*Marine Strategy Framework Directive - EMODnet*	*European waters*	⬛⬛⬛🟧	🟨🟨🟦🟫🟥🟩	-
EMODnet	*European Marine Observation and Data Network*	*European waters*	⬛⬛🟩🟧	🟨🟨🟦⬛⬛⬛	-
SeaDataNet	*Pan-European infrastructure for ocean & marine data management*	*European waters*	⬛⬛🟩🟧	🟨🟨🟦🟫🟥🟩	-
DATA COLLECTION FRAMEWORKS					
TIDE	*Trash Information and Data for Education and Solution*	*Worldwide*	⬛⬛🟩⬛	🟨⬛🟦⬛⬛🟩	yes
-	*LITTERBASE*	*Worldwide*	⬛⬛🟩⬛	🟨🟨🟦🟫🟥🟩	yes
GGGI	*Global Ghost Gear initiative - database and app*	*Worldwide*	🟦🟦⬛🟧	🟨🟨🟦🟫⬛⬛	yes
-	*Resource Watch*	*Worldwide*	⬛⬛🟩⬛	🟨🟨🟦🟫🟥🟩	yes
MEDITS	*International bottom trawl survey in the Mediterranean*	*Mediterranean*	🟦⬛⬛⬛	⬛⬛🟦🟫⬛⬛	-
LARGE-SCALE DATA REPOSITORY/PORTAL INITIATIVES					
COASST	*Coastal Observation and Seabird Survey Team - Marine Debris*	*US*	🟦⬛⬛⬛	🟨🟨⬛⬛🟥⬛	yes
-	*Deep-sea Debris Database - JAMSTEC**	*Pacific & Indian Oceans*	🟦⬛⬛⬛	⬛⬛⬛🟫⬛⬛	-
AMDI	*Australian Marine Debris initiative database*	*Pacific, Oceania*	🟦⬛⬛⬛	🟨🟨⬛⬛⬛⬛	yes
DOME	*DOME (Marine Environment) data portal - an ICES data portal*	*European waters*[1]	⬛⬛🟩🟧	🟨🟨🟦🟫🟥🟩	-
DATRAS	*The Database of Trawl Surveys - an ICES data portal*	*European waters*[1]	⬛⬛🟩⬛	⬛⬛⬛🟫⬛⬛	-
-	*Marine LitterWatch*	*European waters*	🟦⬛⬛⬛	🟨🟨⬛⬛⬛⬛	yes

ACTIVITIES[2]

🟦 Data acqusition
🟩 Collection/compilation
🟦 Analysis
🟧 Coordination

APPLICATION AREA[2]

🟨 Beach
🟦 Water column
🟥 Biological - ingested plastic
🟨 Shoreline
🟫 Sea floor
🟩 Inland water bodies

* Japan Agency for Marine-Earth Science and Technology

[1] Baltic Sea, Skagerrak, Kattegat, North Sea, English Channel, Celtic Sea, Irish Sea, Bay of Biscay and the eastern Atlantic from the Shetlands to Gibraltar

[2] Including but not limited to

Source: UNEP 2021.

Illustrated by GRID-Arendal

Figure 9: A selection of data coordination, collection, repository and portal initiatives

2019; Palatinus et al. 2019; Wichmann et al. 2019; Lebreton et al. 2020; van Sebille et al. 2020). Although technological challenges remain, the data coming from such platforms will be especially important in determining volumes of marine litter including plastics in surface waters, sediments and riverine discharges over large areas, particularly when used with ground calibration (Garaba et al. 2018; Martínez-Vicente et al. 2019; Maximenko et al. 2019; van Sebille et al. 2020).

There are currently 15 major operational monitoring programmes, in different geographical ranges, linked to three types of activity: marine litter action coordination, data collection frameworks, and large-scale data repository and portal initiatives (Maes et al. 2019). To date the data and information being collected remain largely unconnected and fragmented, but efforts are under way to standardize and harmonize collection, analysis and reporting methods (Maximenko et al. 2019; Michida et al. 2019) (Figure 9).

Alongside large-scale monitoring programmes, there are indicator processes and baseline data collection activities at specific locations. These include programmes to meet the requirements of United Nations Sustainable Development Goals (SDGs), for example SDG Indicator 14.1.1 (Index of eutrophication and floating plastic debris density) (GESAMP 2019) and various Regional Seas Conventions and Action Plans with specific plans for marine litter (see Annex 2). A growing number of networks, citizen science projects and participatory processes involved in measuring and tackling marine litter and plastic pollution are yielding results that can assist local decision-making (Hidalgo-Ruiz and Thiel 2015; Wyles et al. 2016; González-Fernández and Hanke 2017; Zettler et al. 2017; Kandziora et al. 2018; Rehn et al. 2018; Turrell 2019). The Global Partnership on Marine Litter (GPML) supports various efforts through the development of a multi-stakeholder digital platform,[2] with the aims of compiling and crowd sourcing different resources including from innovative sources; integrating data from source–to-sea and throughout the plastic life cycle relevant to, for example, SDGs 6 (Clean Water and Sanitation), 11 (Sustainable Cities and Communities), 12 (Responsible Consumption and Production) and 14 (Life Below Water); and connecting stakeholders in order to guide and coordinate action.

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2. https://digital.gpmarinelitter.org

TECHNICAL STANDARDS FOR CERTIFICATION, VERIFICATION, LABELLING AND TRACEABILITY

An important component in the management of marine litter and plastic pollution is the development of technical standards for certification, labelling and verification processes. In the case of beaches and coastal areas there are schemes such as the Blue Flag Programme, Quality Coast Awards, Seaside Awards, Green Coast Awards, and Bandera Azul Ecológica. For plastic products there are a few internationally established and acknowledged standards, and certification and verification schemes, for the manufacturing and processing of plastics. They cover aspects of biodegradability, recycling and degradation during the industrial composting process and in the marine environment (Harrison et al. 2018; UNEP 2018a; UNEP and Consumers International 2020). Examples are International Organization for Standardization (ISO) standards ISO 15279 (recovery and recycling of plastic waste); ISO 22526 (carbon and environmental footprint); ISO/CD 22722 (disintegration of plastic materials in marine habitats); and ISO 18830 (biodegradation test). However, in a review of the biodegradability of plastic bags current international standards and regional test methods were shown to be insufficient in their ability to realistically predict the biodegradability of carrier bags in wastewater, inland waters and marine environments due to shortcomings in existing test procedures, the absence of relevant standards for the majority of unmanaged aquatic habitats, and lack of wider research on the biodegradation of plastic materials under real-world conditions (Harrison et al. 2018).

In addition, there are very few verification schemes for the manufacturing and processing of recyclates, and none that require the listing of constituent polymers or chemical additives in consumer products or provide traceability (UNEP and the International Trade Centre 2017). This lack of information about recyclates is a barrier to increasing recycling rates and the development of markets. Thus there is an urgent need to improve the labelling standards and traceability of plastics. For example, buying products designated as "made from ocean plastic", which are popular with consumers, will not keep plastics from entering the oceans.

The traceability of plastic products throughout their life cycle is also vital to determine points where interventions are likely to be most effective (Ellen MacArthur Foundation 2016). Recent advances have included the use of blockchain technologies to trace the chemicals added to plastics during production and the loss of materials along the supply chain (Roos et al. 2019).

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CHALLENGES AND RESPONSES TO REDUCE MARINE LITTER AND PLASTIC POLLUTION

Over the past four decades there has been a quadrupling of global plastics production (Geyer 2020). Demand continues to grow, with the size of the global plastic market in 2020 estimated to be around US$ 580 billion compared to an estimated US$ 502 billion in 2016 (Statista 2021a). At the same time, it is estimated that less than 10 per cent of the plastics ever produced have been recycled (Dauvergne 2018; Zheng and Suh 2019; Geyer 2020).

One of the main reasons for such a low recycling rate is lack of information about the constituents of plastic products, with a subsequent loss of quality and value through mixing of waste streams (Leslie et al. 2016; Ellen MacArthur Foundation 2021). This represents a loss in the value of packaging waste each year of some US$ 80-120 billion (Ellen MacArthur Foundation 2016). Ultimately it causes millions of tons of plastic waste to be lost to the environment or shipped thousands of kilometres to destinations where the waste is generally burned or dumped in waterways (UNEP 2019a).

Another challenge is the level of GHG emissions associated with the global life cycle of conventional fossil fuel-based plastics; in 2015 these were 1.7 gigatons of carbon dioxide equivalent ($GtCO_2e$); they are projected to grow to approximately 6.5 $GtCO_2e$ by 2050, or 15 per cent of the global carbon budget (Zheng and Suh 2019). The other significant problem is the growing cost of managing plastic waste. It has been estimated that the global cost of municipal solid waste management will grow from US$ 38 billion in 2019 to US$ 61 billion in 2040 under a business-as-usual scenario (Kaza et al. 2018). Even with increased taxes and government regulations, constraints on resources and reduced demand due to stockpiling (Business Research Company 2020), annual ocean plastic pollution is projected to triple by 2040 (The Pew Charitable Trusts and SYSTEMIC 2020).

Concern by the general public, businesses and governments is also growing (Avio et al. 2017; Borrelle et al. 2017; Maeland and Staupe-Delgado 2020), exacerbated by the volumes of

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waste associated with the personal protective equipment and other plastic items used during the COVID-19 pandemic (Adyel 2020).

While there is no single global treaty to reduce marine litter and plastic pollution (Muirhead and Porter 2019; Karasik et al. 2020; Raubenheimer and Urho 2020), many global, regional and national commitments and activities are helping to mobilize the global community to bring an end to marine plastic pollution (UNEP 2018b). For example, municipalities and large firms have been reducing waste flows to landfills (Dauvergne 2018) and regulatory processes are expanding, driven by the growing evidence of the risks posed by plastics and through public pressure (Koelmans et al. 2017a; GESAMP 2020a). There has also been an upsurge in local activism, local government actions to increase kerbside collections and recycling, community clean-ups and public awareness campaigns (Schneider et al. 2018). Successes at the local and national levels are being supported by regional and national legislative efforts which are already aiming to reduce marine litter and plastic pollution directly (Black et al. 2019).

The various international commitments that do exist, include those aimed at reducing plastic pollution and marine litter, especially from land-based sources, for example as part of the 2030 Agenda for Sustainable Development Goal 14), plus international binding agreements, conventions, protocols, initiatives and cooperation processes (United Nations General Assembly 2015; UNEA 2017) (Figure 10). Among them are the United Nations Convention on the Law of the Sea (UNCLOS); the International Convention for the Prevention of Pollution from Ships (MARPOL), the London Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matters and the London Protocol preventing the dumping of waste streams that contain plastic or similar synthetic materials into the marine environment; the Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and their Disposal; the Rotterdam Convention on the Prior Informed Consent Procedure for Certain Hazardous Chemicals and Pesticides in International Trade; and the Stockholm Convention on Persistent Organic Pollutants (POPs) (Chen 2015; Raubenheimer and McIlgorm 2018). In addition, there are other international agreements and soft law instruments that are applicable, as they relate to trade in plastics or support the reduction of marine litter. They include the World Trade Organization (WTO); the Convention on Biological Diversity; the Convention on Migratory Species of Wild Animals; the Food and Agriculture Organization (FAO) Code of Conduct for Responsible Fisheries and the United Nations Fish Stocks Agreement; the Global Programme of Action for the Protection of the Marine Environment from Land-based Activities (UNEP/GPA 2020); the Honolulu Strategy; and the Strategic Approach to International Chemicals Management (SAICM) (Lyons 2019; Birkbeck 2020; Borrelle et al. 2020; The Pew Charitable Trusts and SYSTEMIQ 2020).

Regional arrangements play a vital role in accelerating the uptake of policies and initiatives. Some of the most important for marine litter and plastics are the Regional Seas Conventions and Action Plans,[3] which include various measures to reduce marine litter and plastic pollution, as well as monitoring and public awareness campaigns (UNEP 2018b). In Africa some 30 countries have agreed under the Bamako Convention, the regional instrument related to the Basel, Rotterdam and Stockholm Conventions, to strengthen management of hazardous waste including plastics and electronic waste (e-waste). Some national actions can help reduce particular types of plastic pollution (e.g. those specifically targeting plastic grocery bags, products containing microbeads or plastic bottles, or anti-litter campaigns) (Xanthos and Walker 2017; Dauvergne 2018; Schuyler et al. 2018). In addition, Marine Protected Areas and coastal zone management policies are important policy instruments for waste abatement, especially if implemented on a catchment-wide or ecosystem basis (Windsor et al. 2019).

Overall, the current situation is a mixture of widely varying business practices, increasing levels of plastic production, and very different national regulatory and voluntary arrangements. There is little policy coordination among countries and national and subnational policies are uneven, with loopholes, erratic implementation and inconsistent standards (Dauvergne 2018; Forrest et al. 2019; Birkbeck 2020). Increasing quantities of discarded plastic waste are the product of multiple market failures linked to the low price of fossil fuel feedstocks, the presence of subsidies, poor waste management, low generation and uptake of plastic recyclates, and widespread use and throw away behaviour (Law 2017; UNEP 2019b; Borrelle et al. 2020; The Pew Charitable Trusts and SYSTEMIQ 2020).

As the pressures and complexities of tackling the marine litter and plastic pollution crisis mount up, there is a need to address them through a governance process that takes account of the seriousness of the situation and helps to contextualize the problem globally (Borrelle et al. 2017; Dauvergne 2018; Schneider et al. 2018; Forrest et al. 2019; Maeland and Staupe-Delgado 2020). However, none of the international policies agreed since 2000 includes a global, binding, specific, measurable target limiting marine litter and plastic pollution, leading to calls by some governments, businesses and civil society for a binding global treaty on marine litter and plastic pollution (Muirhead and Porter 2019; Karasik et al. 2020; Raubenheimer and Urho 2020; WWF, the Ellen MacArthur Foundation and BCG 2021).

No single-solution strategy can reduce the annual leakage of plastics to the ocean, even to below 2016 levels, by 2040 (Borrelle et al. 2020; Lau et al. 2020); rather, a number of synergistic system interventions will be needed both upstream and downstream (The Pew Charitable Trusts and SYSTEMIQ 2020). For example, in the absence of any pricing policies for plastic waste (Matheson 2019) various fiscal instruments, such as taxes, fees and charges, deposit-refund schemes, extended producer responsibility (EPR) schemes, tradeable

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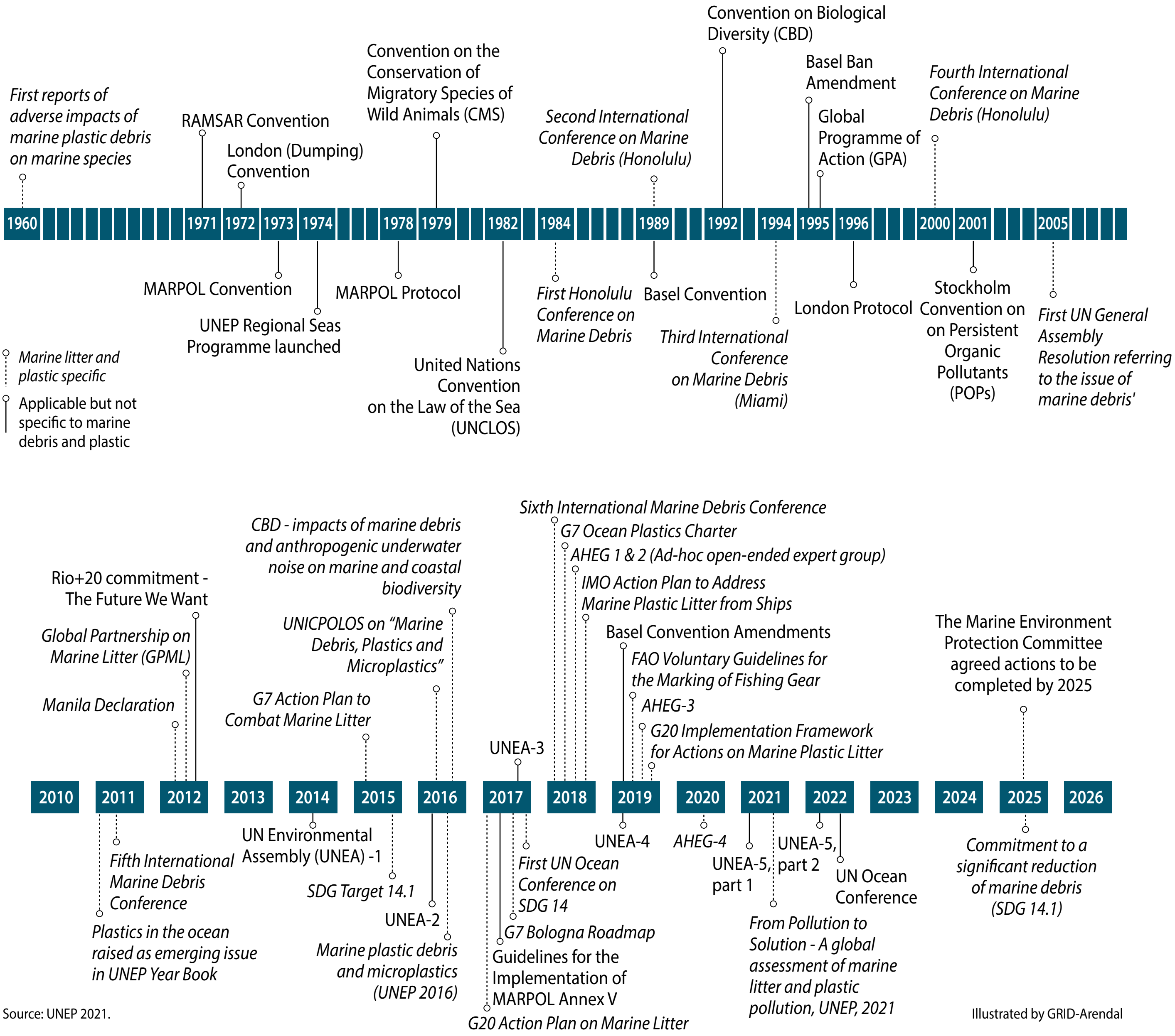
[3] Some of the Regional Seas Conventions and Action Plans have specific plans on marine litter, as have other actors. See Annex II.

permit schemes and subsidies can be used by governments to enhance waste management (Xanthos and Walker 2017; OECD 2019; Parts 2019; Walker et al. 2020). These instruments may need to be adapted to address plastics. For example, EPR is widely considered a cornerstone of waste policy (Filho et al. 2019), but the key to its use in reducing plastic waste will be to incentivize industry to increase recyclability and ecodesign (Forrest et al. 2019). A step towards this goal could be made through greater disclosure about the resins, chemicals and additives used in plastic products, and guidance for consumers and waste brokers on their safe reuse or disposal.

Overall reductions in the total amount of plastic pollution generated will mean phasing out specific plastic products, introducing EPR, and reshaping the established linear take-make-dispose economy to one in which material flows are part of closed-loop, resource-efficient, or circularity approaches (European Commission 2018b; Lieder and Rashid 2015; OECD 2016; European Union 2019b; Forrest et al. 2019; UNEP 2019a; Karasik et al. 2020; Raubenheimer and Uhro 2020).

Concerted efforts at many levels will be needed to move towards circularity with respect to plastics (IRP 2021). These efforts will need to be contextualized and to link business processes and social awareness with policies and consumer actions to significantly reduce the volume of fossil fuel-based plastics being produced; improve the design of products to reduce levels of waste; enhance decentralized recycling of materials (Joshi et al. 2019); eliminate unnecessary, avoidable and problematic plastic waste streams; and improve standards for the regulation of materials such as biodegradable plastics (Dauvergne 2018; Carney Almroth and Eggert 2019; Forrest et al. 2019; Zheng and Suh 2019; Borrelle et al. 2020; Lau et al. 2020; The Pew Charitable Trusts and SYSTEMIQ 2020; UNEP and Consumers International 2020; Ellen MacArthur Foundation 2021; IRP 2021).

Changing attitudes to the problems caused by plastic pollution are causing politicians and industries to consider ways to promote ways to keep the value of plastics in the economy through feedstock substitution and expansion of consumer reuse options (Ellen MacArthur Foundation 2016; UNEP and the



Source: UNEP 2021.

Illustrated by GRID-Arendal

Figure 10: Timeline for selected international marine litter and plastic pollution initiatives, laws and policies

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International Trade Centre 2017; ten Brink et al. 2018; Borrelle et al. 2020; Lau et al. 2020; The Pew Charitable Trusts and SYSTEMIC 2020; UNEP and Consumers International 2020). Many global brand companies have already put in place plans to change their approaches to packaging use, consistent with national-level collection and recycling schemes, and make all packaging reusable, renewable or recyclable. Partnerships such as the Basel Plastic Waste Partnership, the Global Partnership on Marine Litter, the New Plastics Economy Global Commitment and the National Plastic Action Partnerships can help move economies and societies in this direction by showing that recycling works, for example, by making used plastic a valuable commodity, incentivizing recovery, and accelerating the industrialization of polymer-to-polymer technologies (Forrest et al. 2019; Ellen MacArthur Foundation 2020).

Several initiatives aim to "turn off the tap" regarding virgin plastic production (Birkbeck 2020; Borrelle et al. 2020; The Pew Charitable Trusts and SYSTEMIQ 2020) through elimination, expansion of consumer reuse options, or new delivery models, implemented in conjunction with other strategies such as substitution, improving collection and recycling, and secure disposal of residual waste for maximum reduction of plastic pollution flows. Such initiatives may offer the largest reductions of plastic pollution; they can represent a net savings in costs to consumers and producers while reducing greenhouse gas emissions (The Pew Charitable Trusts and SYSTEMIQ 2020). Some actions, such as increasing the volume of bio-based products, may involve heavy reliance on agriculture (Posen et al. 2017; Spierling et al. 2018). Alternatively, green chemistry can help provide significant improvements in materials that are not fossil fuel-based through the design of molecules, materials and products that are more easily recycled and up-cycled than those currently on the market (UNEP 2021).

The production of hundreds of different plastic polymers and products complicates the recycling potential of plastics (Geyer et al. 2016; Zink et al. 2018). The current level of recycling (less than 10 per cent of all plastic waste) is well below global recycling rates for other commodities and resources (Dauvergne 2018; Geyer 2020). Plastic recycling is currently carried out using mechanical and chemical processes. Mechanical recycling is used for non-fibre plastics and, increasingly, for recycled polyester yarns. Chemical recycling, which combines various plastic-to-fuel and plastic-to-plastic technologies, turns plastics into liquids or gases which can be used to make new plastics. Most recycled nylon comes from manufacturing waste and post-consumer waste, such as fishing nets and carpets.

Even if it were scaled up, it would address only a small percentage of the total volume of waste and has high energy requirements (The Pew Charitable Trusts and SYSTEMIQ 2020).

Although research on all aspects of marine litter and plastic pollution is growing rapidly, Maes et al. (2019) conclude that much of this research is still "in its adolescence". They found that risk assessment, plastic fragmentation and assessment tools were under-represented. This is particularly important where uncertainties exist such as the potential risks from chemicals associated with plastics (Burns and Boxall 2018), intercalibration of methods and technologies is needed, or integrative approaches are required (Temmerman et al. 2013). There is also a need for research to provide answers and inputs to policy analyses and assessments, based on evidence and rigorous risk assessments that are fit-for-purpose (Hurley and Nizzetto 2018; Besselling et al. 2019; Karn and Jenkinson 2019; Maeland and Staupe-Delgado 2020).

Overall, the current state of knowledge can provide a reasonable basis upon which to identify research priorities in general, as well as to identify areas where there has been limited research and development funding despite policy and societal needs (de Sá et al. 2018; Carney Almroth and Eggert 2019; Maes et al. 2019). Addressing marine litter and plastic pollution requires multidisciplinary, integrated research coupled with wide cooperation among academic researchers and professionals from different specialist areas and industry.

Based on the findings of the assessment, a number of systemic areas can be identified that would benefit from further investigation. They include cross-cutting issues such as gender and intersectionality (age, marginalized and vulnerable groups), especially in relation to exposure, health effects, attitudes to new innovative technologies and ocean literacy, where there has been virtually no research published in the peer reviewed literature, plus the following:

- Evaluation of the full life cycle for key plastic products, including environmental and health impacts of marine plastics, microplastics and nanoplastics, social and economic costs, loss of ecosystem services, potential implications of new materials, gendered impacts of plastics and alternatives, and risks and impacts of chemicals associated with plastics in food production, aquaculture, agriculture and food safety;

- Development of a risk framework, based on a full life cycle for marine litter and plastic pollution from source to sea, covering ecological, social, economic and health effects;

- Definition of the health and toxicological criteria and testing needed to establish the exposure of humans and wildlife to microplastics in aquatic environments;

- Implementation of open access platforms to enable global mass balance modelling of marine litter and plastics and the fluxes and flows of plastics entering the marine environment from rivers, wastewater treatment plants, waste management, storm sewers as a result of catastrophic events, and maritime sectors;

- Establishment of informatics and harmonized monitoring frameworks, including standard methodologies for sampling, laboratory testing and data collection, to quantify the fluxes and flows of plastics into the environment, the distribution of plastics and microplastics, and the toxicology of microplastics and additives in the environment emanating from plastic pollution, in order to be able to measure the effectiveness and impacts of different interventions and mitigation efforts;

- Definition of core sets of indicators, from source to sea, across the Drivers Pressures State Impacts Response framework in order to monitor progress on the reduction of marine litter and plastic pollution;

- Green chemistry innovation to minimize the use of additives and develop alternative polymers and materials including bio-based ones, based on a full life cycle approach, that are safer and more easily disposed of or recycled, and development of pathways for switching to alternatives;

- Development of ecodesign principles across all major use sectors where plastics are used extensively, and development of cost roadmaps;

- Development of small-scale waste management and recycling technologies that can be located close to sources of plastics waste to help avoid or reduce plastics leakage into the environment;

- Development of standards for plastic certification, traceability and labelling schemes for all plastics linked to consumer use, including biodegradability;

- Policy research on effective measures to reduce plastics including microplastics, such as extended producer responsibility (EPR) schemes, reinforcement of fiscal instruments, standards for plastic certification, traceability and labelling schemes for all plastics used by consumers, and encouraging ecodesign and green chemistry to develop new materials;

- Assessment of social issues related to marine litter and plastic pollution, including gender, consumer perceptions and social drivers, integrating a human rights-based approach that includes meaningful public participation and access to remedies;

- Development of literacy and educational programmes to raise awareness of the issue of marine litter and plastic pollution and to help change human behaviours towards those that reduce mismanagement of plastic waste;

- Behavioural economics and education research on nudges, norms and educational processes beyond knowledge acquisition to influence behavioural changes.

CONCLUSION

This report, emphasizes the urgent need for action on all levels to address the issue of marine litter and plastic pollution

Finding solutions to the problem of marine litter and plastic pollution, requires greater engagement by civil society, businesses, industries and governments to bring about necessary changes in policies, attitudes and practices (Uyarra and Borja 2016; Hartley et al. 2018b; Ashley et al. 2019). Citizens continue to have a major role to play, including by taking action and changing their own behaviours in order to substantially reduce marine litter and plastic pollution. The businesses and industries in which changes will be needed include oil and gas extractors and plastic resin producers, extruders and product manufacturers, automotive manufacturers and textile manufacturers, consumer product companies, packaging companies, retailers, waste hauliers and landfillers, materials recovery operators, waste brokers and recyclers. Policymakers have the opportunity to create the right mix of legislative and fiscal instruments to incentivize greater disclosure, support data sharing and transparency, provide financing, establish a transparent and effective regulatory environment, and support research and development to address the challenge of marine litter and plastic pollution.


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ANNEX I: RATIONALE

The United Nations Environment Assembly (UNEA) has adopted several key resolutions on marine litter and plastic pollution, at its meetings.[4] In 2016 UNEP published a report, *Marine Plastic Debris and Microplastics – Global Lessons and Research to Inspire Action and Guide Policy Change* (UNEP 2016). This report focused on identifying the key sources and pathways, along with possible measures and the best available techniques and environmental practices to prevent marine litter and microplastics accumulation in the marine environment.

In 2019 the Executive Director of UNEP was requested to "strengthen scientific and technological knowledge with regard to marine litter including marine plastic litter and microplastics" by providing an update to the 2016 assessment based on "available scientific and other relevant data and information… on sources, pathways and hazards of litter, including plastic litter and microplastics pollution, and its presence in rivers and oceans; scientific knowledge about adverse effects on ecosystems and potential adverse effects on human health; and environmentally sound technological innovations".

The new 2021 assessment, *From Pollution to Solution: A Global Assessment of Marine Litter and Plastic Pollution*, examines the magnitude and severity of the problem and reviews existing solutions and actions. It provides a comprehensive update on current research and knowledge gaps concerning direct impacts on marine life, the risks posed to ecosystems and human health, and social and economic costs. The assessment describes and quantifies, where possible, the sources of marine litter and plastic pollution and their direct and indirect pathways into and within the oceans, citing improvements in monitoring systems, observation technologies and analytical methods. An overview is presented of the potential effectiveness of different actions and policies, including remedial processes, and a range of economic, technological and legislative solutions.

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[4] UNEP/EA.1/Res.6: Marine plastic debris and microplastics (2014); UNEP/EA.2/Res.11: Marine plastic litter and microplastics (2016); UNEP/EA.3/Res.7: Marine litter and microplastics (2017); UNEP/EA.4/Res.6: Marine plastic litter and microplastics (2019); UNEP/EA.4/Res.9: Addressing single-use plastic products pollution (2019).

ANNEX II: REGIONAL ACTION PLANS ON MARINE LITTER[5]

Name	Organization/entity	Year	Link
Regional Action Plan on Marine Litter in the Arctic	Protection of the Arctic Marine Environment (PAME)	2021	https://digital.gpmarinelitter.org/action_plan/10017
Regional Action Plan for Marine Litter in the Baltic Sea	Helsinki Convention/Baltic Marine Environment Protection Commission (HELCOM)	2015	https://digital.gpmarinelitter.org/action_plan/197
Black Sea Marine Litter Regional Action Plan	Bucharest Convention/Commission the Protection of the Black Sea Against Pollution	2018	https://digital.gpmarinelitter.org/action_plan/194
Regional Action Plan on Marine Litter	Coordinating Body for the Seas of East Asia (COBSEA)	2019	https://digital.gpmarinelitter.org/action_plan/196
Regional Plan on Marine Litter Management in the Mediterranean	Convention for the Protection of the Mediterranean Sea Against Pollution (Barcelona Convention)/Mediterranean Action Plan	2013	https://digital.gpmarinelitter.org/action_plan/198
Regional Action Plan for Prevention and Management of Marine Litter in the North-East Atlantic	OSPAR Commission / Convention for the Protection of the Marine Environment of the North-East Atlantic	2014	https://digital.gpmarinelitter.org/action_plan/201
NOWPAP Regional Action Plan on Marine Litter	Northwest Pacific Action Plan (NOWPAP)	2008 (update expected 2021)	https://digital.gpmarinelitter.org/action_plan/200
Pacific Regional Action Plan – Marine Litter (2018-2025)	Noumea Convention/Secretariat of the Pacific Regional Environment Programme (SPREP)	2018	https://digital.gpmarinelitter.org/action_plan/205
Regional Action Plan for the Sustainable Management of Marine Litter in the Red Sea and Gulf of Aden	Regional Organization for the Conservation of the Environment of the Red Sea and Gulf of Aden (PERSGA)	2018	https://digital.gpmarinelitter.org/action_plan/203
Regional Marine Litter Action Plan for South Asia Seas Region	South Asia Co-operative Environment Programme (SACEP)	2019	https://digital.gpmarinelitter.org/action_plan/204
Basura Marina en la Region del Pacifico Sudeste	Permanent Commission for the South Pacific (CPPS)	2007	https://digital.gpmarinelitter.org/action_plan/238
Western Indian Ocean Regional Action Plan on Marine Litter	Nairobi Convention	2018	https://digital.gpmarinelitter.org/action_plan/199
Regional Action Plan on Marine Litter Management for the Wider Caribbean Region	Cartagena Convention – UNEP Caribbean Environment Programme (CEP)	2014	https://digital.gpmarinelitter.org/action_plan/195
ASEAN Regional Action Plan for Combating Marine Debris in the ASEAN Member States	Association of Southeast Asia Nations (ASEAN)	2021	https://digital.gpmarinelitter.org/action_plan/10008
G7 Action Plan to Combat Marine Litter	Group of 7	2015	https://digital.gpmarinelitter.org/action_plan/190
G20 Action Plan on Marine Litter	Group of 20	2017	https://digital.gpmarinelitter.org/action_plan/191
Action Plan to Address Marine Plastic Litter from Ships	International Maritime Organization (IMO)	2018	https://digital.gpmarinelitter.org/action_plan/237
APEC Roadmap on Marine Debris	Asia-Pacific Economic Cooperation (APEC)	2019	https://digital.gpmarinelitter.org/project/177

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[5] The development of draft Regional Action Plans on Marine Litter is under way in the Caspian, Northeast Pacific, and Western, Central and South Africa regions.

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