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DROWNING IN PLASTICS

MARINE LITTER AND PLASTIC WASTE VITAL GRAPHICS

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Forewords

Global plastic production has risen exponentially over the last decades – now amounting to some 400 million tonnes per year. Although plastic serves many useful purposes, its rapidly growing production and consumption, coupled with a lack of a circular approaches – keeping plastic in the economy and out of the environment – and the extensive leaking of microplastics into nature, all constitute an urgent environmental emergency. Currently, it is estimated that 19-23 million tonnes of plastic leaks into aquatic ecosystems annually – from lakes to rivers to seas – from land-based sources. Exacerbated by contributions from sea-based sources, this combined plastic leakage is having major impacts on ecosystems, economies and society – including on human health.

The aim of this Vital Graphics publication is to provide an overview of the current global marine litter and plastic pollution challenge and its effect on the environment using graphic visualisations – each covering central topics of the challenge and related technical, scientific and policy perspectives. It covers the broad area of marine litter and plastic pollution, including production and consumption of plastic worldwide, chemical composition of plastic material, major sources of plastic leakage to the marine environment and impacts on ecosystems, human health and the economy. The publication builds on the first Marine Litter Vital Graphics published in 2016, capturing the latest trends and developments and expanding the focus to include technical and operational management solutions to removing unnecessary, avoidable and problematic plastics, enhancing circularity and improving plastic waste management – as well as policy and governance frameworks that can address the challenge from a local to global level.

The publication is developed jointly by UNEP, the Secretariat of the Basel, Rotterdam and Stockholm Conventions and GRID-Arendal, drawing on these entities' broad expertise across different thematic areas. It reflects the multi-sectoral nature of this environmental challenge and the need for a multi-pronged approach – addressing it from scientific, technical and policy angles. With much still unknown about the distribution and impacts of plastic on the marine environment and human health – the publication reflects current state-of-the-art knowledge on the global marine litter and plastic challenge and what solutions can be implemented to avoid both known and potential impacts, while global research continues.

The contributions of this report should be seen as complementary to UNEP's new scientific assessment, From Pollution to Solution, aiding in visually communicating its findings to policymakers and practitioners worldwide, while enabling stronger global advocacy for a transformation away from business as usual.

Our hope is that together, these publications can help guide and support policy processes on marine litter and plastic pollution worldwide – providing a foundation for evidence-based action to stimulate innovative, circular solutions across the life cycle of plastic products from source to sea.

Susan Gardner

Director
Ecosystems Division
UNEP

9.2 billion tonnes. That is the total amount of plastic estimated to have been made between 1950 and 2017. More than half this plastic has been produced since 2004. Of all the plastic discarded so far, some 14% has been incinerated and less than 10% has been recycled. And the remainder? It has either been disposed of in landfills and dumps or released into the environment, inlcuding the oceans.

Take a moment to think about these figures. The 9.2 billion tonnes of plastic ever produced are as heavy as 28,000 Empire State Buildings in New York, or almost 2 billion elephants. Today, approximately 438 million tons of plastic are produced per year.

By now we are all painfully aware that plastic waste poses a serious threat to our environment, including both marine and terrestrial ecosystems. What many of us don't know is that microplastics find their way into the food we eat, the water we drink and even the air we breathe. By some estimates, people consume more than 50,000 plastic particles per year – and many more if inhalation is considered. Many plastic products contain hazardous additives. These additives may pose a significant threat to our health. As long as plastic waste is dumped and subject to open burning, toxic chemicals will continue to be released into the environment.

Our triple planetary crisis – climate change, biodiversity loss and pollution, including plastic pollution – is having the greatest impacts on the world's poorest and most vulnerable populations. Segments of these populations predominantly work in the informal waste sector and/or live in the vicinities of open dumpsites. Plastic pollution directly and indirectly threatens the full and effective enjoyment of all human rights, including the rights to life, water and sanitation, food, health, housing, culture and development.

The Covid-19 pandemic has not only highlighted our continued reliance on plastic products, but also exposed weaknesses in our infrastructure and our ability to manage plastic waste in an environmentally sound manner. The plastic waste crisis is truly an issue of global concern requiring immediate action from policy makers, regulators, industry and civil society.

The Basel Convention, the most comprehensive global environmental treaty dealing with hazardous and other wastes, offers an important part of the solution. In a landmark decision taken in 2019, Parties to the Basel Convention unanimously adopted the Plastic Waste Amendments, which are now binding on 186 States. By extension, the legally binding provisions of the Basel Convention, which apply controls on the global trade in hazardous and other waste, now apply to plastic waste. In addition to ensuring the trade in plastic waste is more transparent and better regulated, under the Basel Convention governments must take steps not only to ensure the environmentally sound management of plastic waste, but also to tackle plastic waste at its source. These are powerful incentives for governments and other key players to strengthen national and regional capacities for environmentally sound recycling, thereby creating jobs, and to promote innovation, favouring the investment in alternatives to plastic and the phasing out of toxic additives.

The Basel Convention is not the only instrument at our disposal to tackle plastic pollution. The Stockholm Convention on Persistent Organic Pollutants, which requires Parties to prohibit, eliminate and restrict the production, use, import and export of a number of hazardous chemicals, plays a pivotal role in reducing hazardous additives we find in plastic, ensuring it is safer for use and easier to recycle. In addition, the UNEP Regional Seas Programme provides critical regional governance of marine plastic pollution. To top it off, all eyes are on the United Nations Environment Assembly, which will meet again in 2022, to discuss further international action to address the global plastic pollution crisis.

Using powerful maps and graphics, this publication strikes a balance: relying on the latest science, it alerts us to the complex challenges posed by our plastic waste problem. At the same time, it highlights solutions for policy- and decision-makers in the public and private sectors, from innovation and financial mechanisms to regulation and infrastructures.

For this is our problem, and we need to work collaboratively, to ensure our fight against plastic waste and pollution becomes a joint success story.

Rolph Payet

Executive Secretary
Secretariat of the Basel, Rotterdam and Stockholm Conventions

Abbreviations, acronyms and units of measurement

AHEG	Ad hoc open-ended expert group on marine litter and microplastics
ALDFG	Abandoned, lost or otherwise discarded fishing gear
APEC	Asia-Pacific Economic Cooperation
ASEAN	Association of Southeast Asian Nations
BPA	Bisphenol A
BRS	Basel, Rotterdam and Stockholm Conventions
CBD	Convention on Biological Diversity
CIS	Commonwealth of Independent States
cm	Centimetres
CMS	Convention on the Conservation of Migratory Species of Wild Animals
ECHA	European Chemicals Agency
EEA	European Environment Agency
EPR	Extended producer responsibility
EPS	Expanded polystyrene
ESM	Environmentally sound management
EU	European Union
FADs	Fish aggregating devices
FAO	Food and Agriculture Organization of the United Nations
GES	Good Environmental Status
GESAMP	Group of Experts on the Scientific Aspects of Marine Environmental Protection
GPA	Global Programme of Action for the Protection of the Marine Environment from Land-Based Activities
GPML	Global Partnership on Marine Litter
HDPE	High-density polyethylene
IMO	International Maritime Organization
ISO	International Organization for Standardization
ISSCFG	International Standard Statistical Classification of Fishing Gear
ISWA	International Solid Waste Association
kg	Kilograms
LDPE	Low-density polyethylene
LLDPE	Linear low-density polyethylene
MARPOL	International Convention for the Prevention of Pollution from Ships
MEPC	Marine Environment Protection Committee
mm	Millimetres
MSFD	Marine Strategy Framework Directive
MSW	Municipal solid waste
MT	Million metric tonnes (or megatonnes)
µm	Micrometres
NAFTA	North American Free Trade Agreement
OECD	Organisation for Economic Co-operation and Development
OSPAR	Convention for the Protection of the Marine Environment of the North-East Atlantic
PCBs	Polychlorinated biphenyls
PE	Polyethylene
PET	Polyethylene terephthalate
PHA	Polyhydroxyalkanoate
PIC	Prior informed consent
PLA	Polylactic acid
POPRC	Persistent Organic Pollutants Review Committee
POPs	Persistent organic pollutants
PP	Polypropylene
PPA	Polyphthalamide
PPE	Personal protective equipment
PS	Polystyrene
PVC	Polyvinyl chloride
Res.	Resolution
SAC	Scientific Advisory Committee
SDG	Sustainable Development Goal
t	Tonnes (tonnes in this publication refers to metric tonnes)
TBM	Transboundary movements
UNCLOS	United Nations Convention on the Law of The Sea
UNEA	United Nations Environment Assembly
UNEP	United Nations Environment Programme
UNGA	United Nations General Assembly
US$	United States dollars
USA	United States of America
US EPA	United States Environmental Protection Agency
UV	Ultraviolet
WEF	World Economic Forum
WHO	World Health Organization
WRAP	Waste and Resources Action Programme (United Kingdom)
WWF	World Wide Fund for Nature

Introduction

This publication aims to provide a complete overview of the global challenges related to marine litter and plastic waste through a combination of condensed descriptions of key thematic areas and graphic illustrations that visually display trends, challenges, interlinkages and solutions.

The publication is part of the Vital Graphics series, which illustrates complex environmental issues using easily accessible graphics. It covers marine litter and plastic waste challenges from a complete systems perspective. It has been developed as a collaborate effort between the United Nations Environment Programme (UNEP), the Secretariat of the Basel, Rotterdam and Stockholm Conventions (BRS Secretariat) and GRID-Arendal, drawing on experts from all three organizations as well as external specialists.

The publication is structured to provide first a general overview of modern society's use of plastics, covering plastic production, consumption and waste generation. It then looks at the main sources and pathways of marine plastic pollution, highlighting important sources such as packaging, agriculture, fisheries and aquaculture, microplastics, and special events such as natural disasters and the coronavirus disease (COVID-19) pandemic. This is followed by further elaboration of the fate and impacts of plastic pollution in the marine environment, human health impacts of marine plastic waste, and economic costs for society.

Based on the picture of the current situation, the publication moves on to cover possible solutions to the overall plastics challenge, addressing various components. It describes challenges and possible solutions in the different parts of the waste hierarchy, from waste prevention and minimization to waste collection, recycling, recovery and disposal. It also provides an overview of challenges and solutions related to bioplastics, waste management in developing countries and socio-economically disadvantaged areas, and challenges and opportunities related to gender balance in waste management.

Finally, there is an overview of governance and policy solutions, covering the Basel Convention, national policies, global responses through the United Nations Environment Assembly (UNEA), other global and regional initiatives, monitoring and assessment components, and broader systemic perspectives.

The publication is structured in 27 individual sections covering thematic components of this issue through a combination of text and graphics. It can be read in its full length or used as a resource for condensed and graphically illustrated information on these topics. The final chapter is an executive summary of the entire publication.

This publication is written in a language that should be accessible to environmental policy makers and practitioners without special waste or pollution expertise. It is intended to guide and inform actions to address the marine plastic challenge from the local to the global level. It should therefore provide a good entry point for addressing the different aspects of this complex area.

Global plastics production and consumption

During World War II plastics production boomed. The war drove technological advances in the petrochemical industry, resulting in new cheap and flexible plastics used in a multitude of products including aircraft parts (Freinkel 2011). The post-war years were a period of worldwide economic expansion and the starting point for mass production of plastics for consumer products. Many plastic manufacturing factories that once supported the production of items with military applications were retooled as plastics became an everyday material. Because of their strength and light weight, among other characteristics, plastics are used in a wide range of products (Parker 2020).

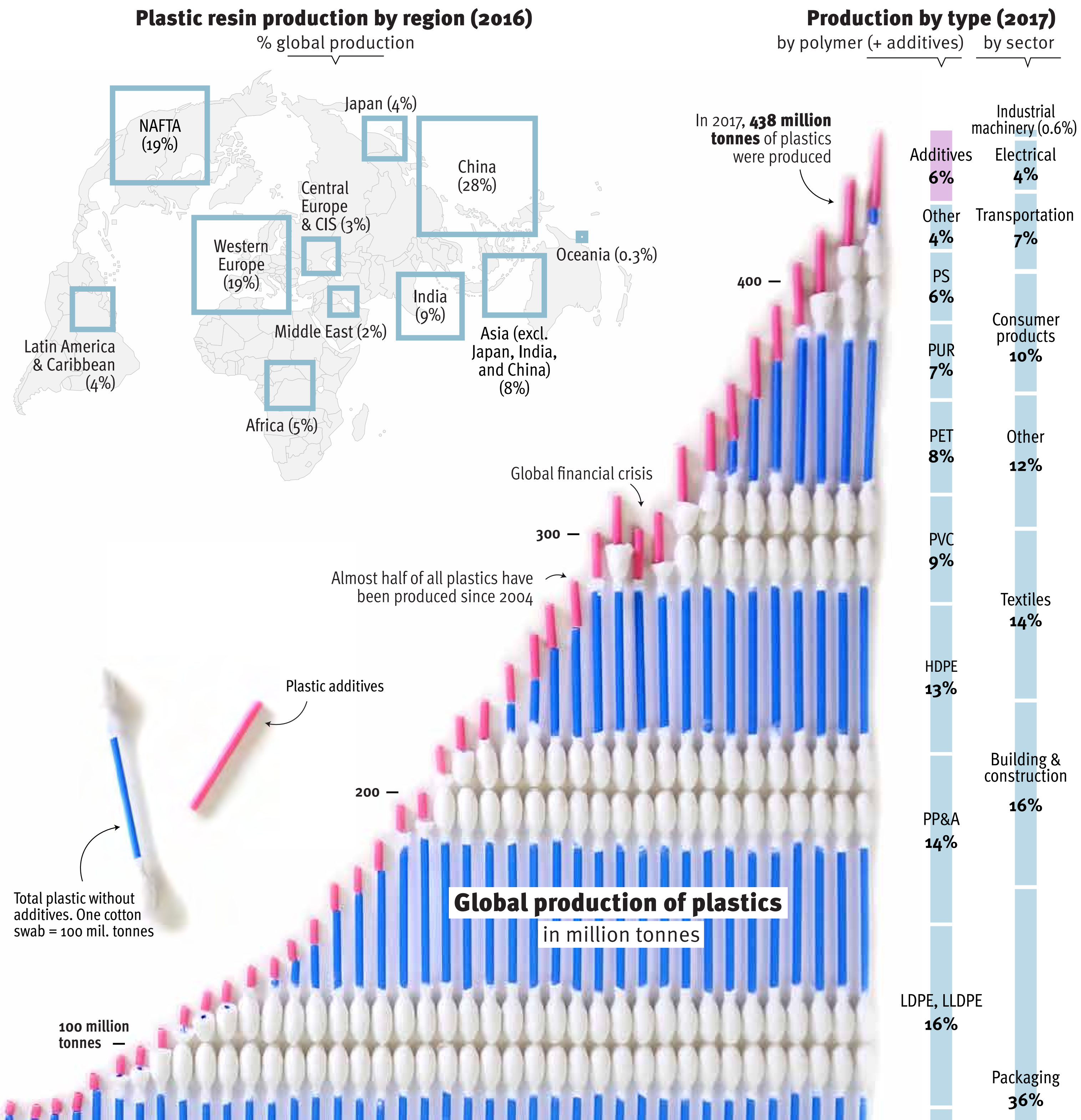
From the 1950s rapid growth occurred in the use of plastics for packaging, in building and construction, and in other sectors. Reliance on plastics has continued to grow. Annual global production of primary fossil fuel-based (or "fossil-based") plastics increased from around 2 million tonnes by 1950 to some 438 million tonnes in 2017 (Geyer 2020). More than half of all plastics have been produced since 2004. The COVID-19 pandemic temporarily slowed plastic production, with an estimated decrease of around 0.3% in 2020 (Statista 2021). Consumer demand has fallen in the case of some products and increased in that of others. There has been a massive increase in the production of items such as single-use plastic personal protective equipment and certain types of packaging (e.g. for food takeaways) (see Chapter 11). If global trends on plastic demand continue, it is estimated that by 2050 annual global plastic production will reach over 1,100 million tonnes (Geyer 2020).

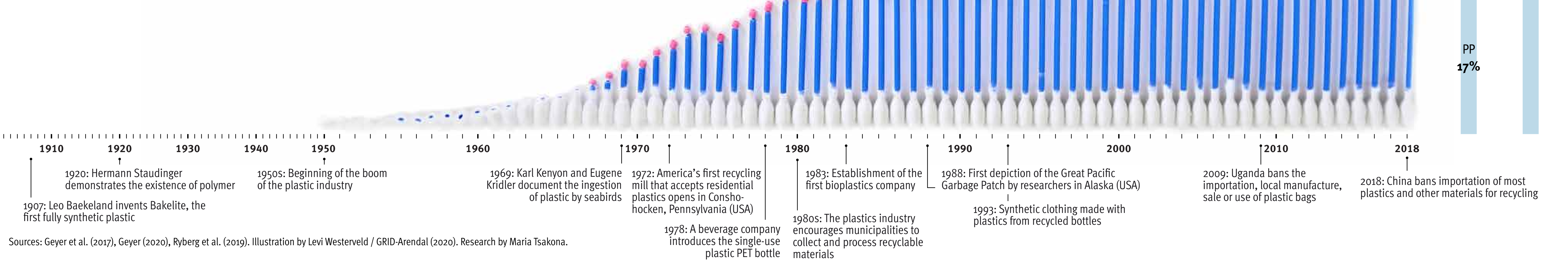
Up to 99% of plastics are made from polymers from non-renewable hydrocarbons, mostly oil and natural gas. A small percentage are made from a range of polymers such as starch, cellulose, sugars and vegetable oil (British Plastics Federation 2019). Through the addition of additives such as plasticizers, flame retardants and dyes (see Chapter 3) plastics can take on various characteristics and colours, which has facilitated the introduction of thousands of plastic products into the market (American Chemistry Council 2020).

Historically, Europe and North America have dominated global plastics production. However, in the last decade Asia has emerged as a significant producer, with China accounting for 28% of total plastic resin production and 64% of synthetic fibre production in 2016 (UNEP 2018; Geyer 2020). Regional differences in the volume of plastics production are driven by user demand, the price of fossil fuel feedstocks, and investments made in the petrochemical industry. For example, since 2010 over US$ 200 billion has been invested in the United States in new plastic and chemical plants, stimulated by the low cost of raw materials (American Chemistry Council 2019). In the European Union (EU), too, heavy investments have been made in the plastics industry, which employs over 1.6 million people with a turnover of more than 360 billion euros per year (PlasticsEurope 2019). In China in 2016 there were over 15,000 plastic manufacturing companies, generating more than US$ 366 billion in revenue (Barrowclough and Birkbeck 2020).

In 2017 the global plastics market was dominated by thermoplastics – polymers that can be melted and recast. Thermoplastics include polyethylene (PE), polyethylene terephthalate (PET), polypropylene (PP), polyvinyl chloride (PVC), polystyrene (PS) and polyphthalamide (PPA), which together represent 86% of all plastics. Polyethylene, which includes low-density polyethylene (LDPE), linear low-density polyethylene (LLDPE) and high-density polyethylene (HDPE), is the most popular thermoplastic: 31% of all plastics are polyethylene (Geyer 2020).

The most commonly produced plastic consumer products include packaging made from LDPE (e.g. bags, containers, food packaging film), containers made from HDPE (e.g. milk bottles, shampoo bottles, ice cream tubs), and PET (e.g. bottles for water and other drinks). Together these products account for





Sources: Geyer et al. (2017), Geyer (2020), Ryberg et al. (2019). Illustration by Levi Westerveld / GRID-Arendal (2020). Research by Maria Tsakona.

around 36% of plastics use in the world (UNEP 2018; Geyer 2020). Most of them (e.g. disposable cups, plates, cutlery, takeaway containers, carrier bags) are used for only a short period, many for less than a day (Resource Futures 2018). The use of plastics in building and construction, textiles, transportation and electrical equipment also accounts for a substantial share of the plastics market. Plastic items used for such purposes generally have longer life spans than, for example, plastic packaging. They may be in use for periods ranging from around five years (e.g. textiles and electrical equipment) to more than 20 years (e.g. construction materials, industrial machinery) (Resource Futures 2018).

Plastic consumption differs among countries and communities, with some form of plastic having made its way into most people's lives. North America (i.e. the North American Free Trade Agreement or NAFTA region) accounts for 21% of global plastic consumption, closely followed by China (20%) and Western Europe (18%) (UNEP 2018). In North America and Europe there is high per capita plastic consumption (94 kg and 85 kg/capita/year, respectively) (Euromap 2016). In China there is lower per capita consumption (58 kg/capita/year), but high consumption nationally because of its large population (Euromap 2016; UNEP 2018).

CHAPTER 2

The plastics life cycle

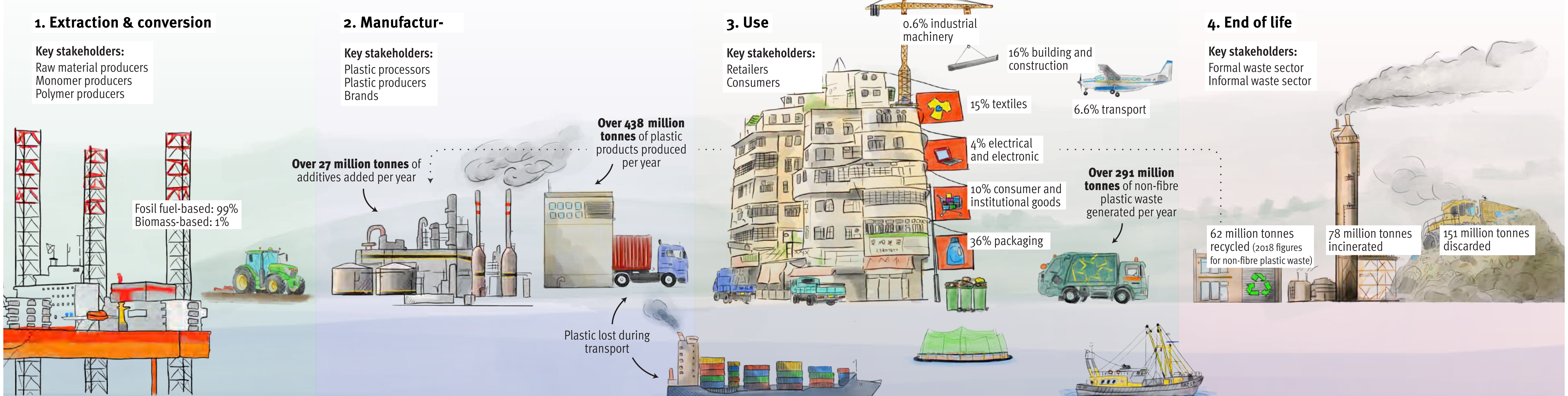
The plastics life cycle includes extraction of raw materials; design and production; packaging and distribution; use and maintenance; and recycling, reuse, recovery or final disposal. After plastic items have been consumed or used, these items may follow several different routes. Some are collected and sorted through formal or informal waste management schemes or by manufacturers, turned into plastic pellets or flakes, and re-enter the production and use phase (UNEP and GRID-Arendal 2016). However, most plastics are incinerated, openly burned, disposed of in landfills/dumpsites, or escape into the environment (Geyer et al. 2017; Geyer 2020). It is estimated that since the 1950s no more than 10% of plastics have re-entered the value chain (i.e. have been recycled or reused) (Geyer 2020). Removal from the value chain has both economic impacts, due to loss of resources, and environmental impacts.

Plastics can escape into the environment at every stage of their life cycle (GESAMP 2016; ISWA 2017; UNEP 2020). During production, transport or conversion, plastic pellets or fibres may be lost (UNEP 2018). It has been estimated that 60-99 million tonnes of mismanaged plastic waste were produced globally in 2015, and that this amount could increase to 155-265 million tonnes per year by 2050 under a business as usual scenario (Lebreton and Andrady 2019). The main leakage of plastics to the environment usually occurs following use and during disposal, with large volumes lost as a result of littering and lack of environmentally sound waste management practices. An estimated 19-23 million tonnes of plastic waste entered aquatic ecosystems from land-based sources in 2016 (Borrelle et al. 2020). Sea-based pollution from sources such as shipping, fishing, offshore installations or dumping of refuse at sea also contributes significantly to the loss of plastics to the environment (Veiga et al. 2016). The fishing industry alone is thought to be responsible for some 1 million tonnes of plastic waste (e.g. plastic nets, fishing line) entering the ocean each year (Siegel 2018).

Developing a circular plastic economy and limiting plastic pollution require multilevel actions by different stakeholders. Among these stakeholders are waste management and other government authorities, chemical and plastic manufacturers, consumers and companies that produce consumer goods, retailers, waste management enterprises, plastic recyclers and others, including the informal sector (UNEP 2018; Hahladakis 2020).

Actions are needed at many levels. They include greater use of renewable energy in materials production; recycling and demand management strategies; replacing fossil fuel feedstock for plastics with alternatives; improving standards for design and recycling; reducing the content of hazardous additives in plastic products; valuing the price of plastics more effectively; strengthening plastic waste management infrastructures; increasing public awareness; and shifting to business models, such as reuse systems, that keep plastic products at their highest value within the economy for a longer time (Dauvergne 2018; Forrest et al. 2019; UNEP 2019; Zheng and Suh 2019).

The plastics life cycle



Sources: UNEP (2018), UNEP (2019), EEA (2020), Geyer (2020). Illustration by Levi Westerveld / GRID-Arendal (2021). Research by Maria Tsakona.

Plastic additives

Every plastic item contains additives that determine the properties of the material and influence the cost of production (Stenmarck et al. 2017). Typical additives include stabilizers, fillers, plasticizers, colourants, as well as functional additives such as flame retardants and curing agents. Some plastic additives are hazardous to human health and the environment (Stenmarck et al. 2017; Wiesinger et al. 2021). The amount of additives contained in plastics varies depending on the additives' function. For example, additives in polyvinyl chloride (PVC) can constitute up to 80% of the total volume (Hahladakis et al. 2018).

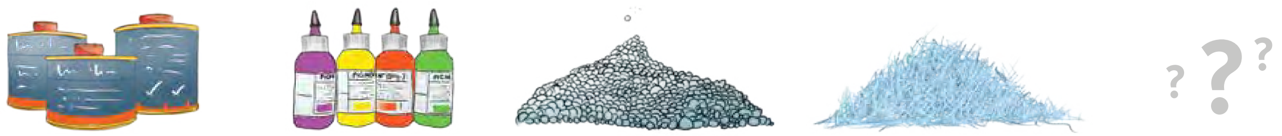
Many different chemicals are used as plastic additives. A randomly chosen plastic product generally contains around 20 additives (van Oers et al. 2011). Flick (2004) lists 7,000 plastic additives. Nevertheless, the identities and concentrations of additives are generally not listed on products. The most commonly used additives are fillers (50% of the world additives market), followed by plasticizers (22%, of which more than 80% are phthalate plasticizers; van Oers et al. 2011). According to the European Chemicals Agency (ECHA), over 400 plastic additives are used in the EU in high volumes (ECHA 2021).

Plastics are composed of chains of polymers. Additives may be weakly bound to the polymers or react in the polymer matrix. The weakly bound additives can leach out of the plastics during normal use, when in landfills, or following improper disposal in the environment (Wagner and Schlummer 2020). Additives may also degrade to form other toxic molecules. Plastic fragmentation into microplastics and nanoplastics (see Chapter 5) can allow chemical additives to move in the environment far from the point of use (Hahladakis et al. 2018). Once released, some additives and derivatives may persist in the environment and bioaccumulate in organisms. They can have adverse effects on human health and biota (Stenmarck et al. 2017). A recent review by the United States Environmental Protection Agency (US EPA) revealed that out of 3,377 chemicals potentially associated with plastic packaging and 906 likely associated with it, 68 were ranked by ECHA as "highest for human health hazards" and 68 as "highest for environmental hazards" (Groh et al. 2019). (For the impacts of plastics on the marine environment and human health impacts of marine waste, see Chapters 13 and 14, respectively.)

Additives present risks in recycled products, as they are difficult to remove. When plastic products are recycled, it is highly likely that the additives will be integrated into the new products (Wagner and Schlummer 2020). Absence of transparency and reporting across the value chain often results in lack of knowledge concerning the chemical profile of the final products. For example, products containing brominated flame retardants have been incorporated into new plastic products (Leslie et al. 2016; Pivnenko 2017; Stenmarck et al. 2017; Kuang et al. 2018; Turner 2018). Flame retardants are a group of chemicals used in electronic and electrical equipment, textiles, furniture and construction materials which should not be present in food packaging or child care products. A recent study found brominated dioxins as unintentional contaminants in toys made from recycled plastic electronic waste that contained brominated flame retardants (Petrlík et al. 2018). Brominated dioxins have been found to exhibit toxicity similar to that of chlorinated dioxins. They can have negative developmental effects and negative effects on the nervous system and interfere with mechanisms of the endocrine system (Piskorska-Pliszczyńska et al. 2014).

Additives can also be problematic if waste is burned, especially when burning is uncontrolled or takes place in low-technology incinerators, as is common in many developing countries. Incomplete combustion can cause emissions of hazardous substances such as acid gases and ash which can contain persistent organic pollutants (POPs) such as dioxins (Hahladakis et al 2018).

Five types of plastic additives



Functional
Includes, for example, stabilizers, antistatic agents, flame retardants, plasticizers, lubricants, slip agents, curing agents.

Colourants
Substances such as dyes or pigments added to give colour to plastic. Some of them are added to give a bright transparent colour.

Fillers
Added to change and improve physical properties of plastics. They can be minerals, metals, ceramics, bio-based, gases, liquids, or even other polymers.

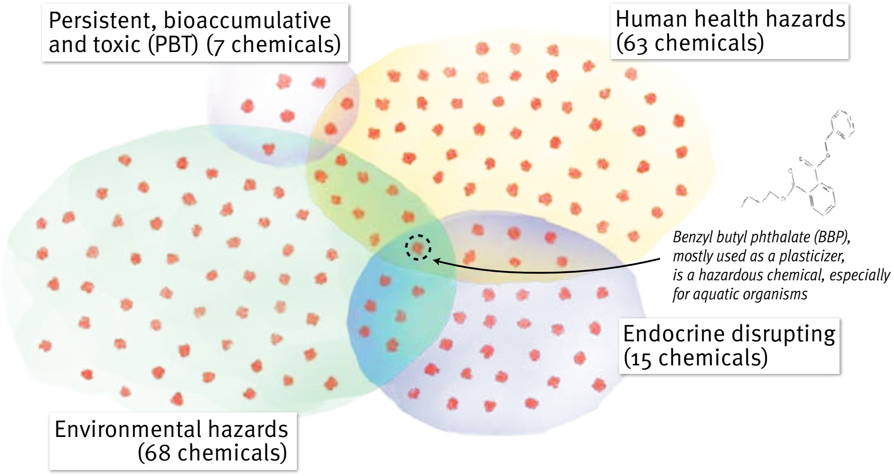
Reinforcement
Used to reinforce or improve tensile strength, flexural strength and stiffness of the material. For example: glass fibres, carbon fibres.

NIAS
Non-intentionally added substances. They arrive in products from processes, such as reaction by-products or breakdown products.

Source: Hansen et al. (2013). Illustration by GRID-Arendal (2020).

Hazardous chemicals in plastics

A 2018 study found that 3,377 chemicals are potentially associated and 906 chemicals are likely associated with plastic packaging. Out of these, 148 have been identified as most hazardous (Groh et al. 2018).



Source: Groh et al. (2018). Illustration by GRID-Arendal (2020).

A number of additives identified as hazardous to humans and/or the environment are regulated internationally (Rodrigues et al. 2018). The Stockholm Convention on Persistent Organic Pollutants (POPs) is a global treaty to protect human health and the environment from chemicals that remain intact in the environment for long periods, become widely distributed geographically, accumulate in the fatty tissue of humans and wildlife, and have harmful impacts on human health or on the environment. It requires Parties to prohibit, eliminate and/or restrict the production, use, import and export of listed intentionally produced POPs. It also requires them to reduce or eliminate releases from unintentionally produced POPs and has provisions on the environmentally sound management of stockpiles and wastes consisting of, containing or contaminated with POPs. Each Party to the Convention is to develop and update an implementation plan to limit or phase out production, use and releases of the POPs. Currently, the Convention regulates a small fraction of the hazardous chemicals contained in plastics and plastic waste. Some of these chemicals are still used as a result of exemptions. Moreover, a large number of additives and associated derivatives still do not fall under current regulations.

Other additives proven to be harmful such as cadmium, chromium, lead and mercury (regulated under the Minamata Convention on Mercury), which have previously been used in plastic production, are banned in many jurisdictions. Nevertheless, they are still routinely found in some plastic packaging including food packaging (Whitt et al. 2016; Lahimer et al. 2017; Alam et al. 2018). The use of the additive bisphenol A (BPA) in plastic baby bottles is banned in many parts of the world, but is not restricted in some low-income countries (Yates et al. 2021).

CHAPTER 4

Global plastic waste generation

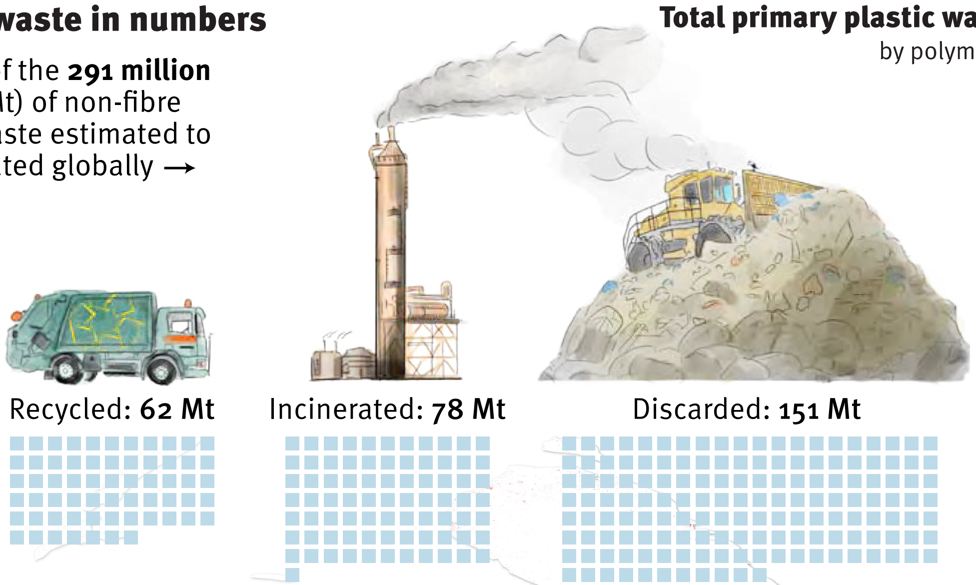
Approximately 9.2 billion tonnes of plastics have been produced since 1950. Only about 30% of these plastics remain in use, resulting in the generation of some 6.9 billion tonnes of primary plastic waste around the world to date (Geyer 2020). This plastic waste is made up of 81% polymer resin, 13% polymer fibres and 32% additives. In 2018 more than 343 million tonnes of plastic waste were generated, 90% of which was composed of post-consumer plastic waste (industrial, agricultural, commercial and municipal plastic waste) (Geyer 2020). The rest was pre-consumer waste from resin production and manufacturing of plastic products (e.g. materials rejected due to unsuitable colour, hardness, or processing characteristics).

Solid waste generation per capita is 0.6-1.0 kg/day in low-income countries, 0.8-1.5 kg/day in middle income countries, and 1.1-4.5 kg/day in high-income countries (Kaza et al. 2018; Ritchie and Roser 2018). On average, 12% of the mass of all municipal solid waste (MSW) consists of plastics (Kaza et al. 2018).

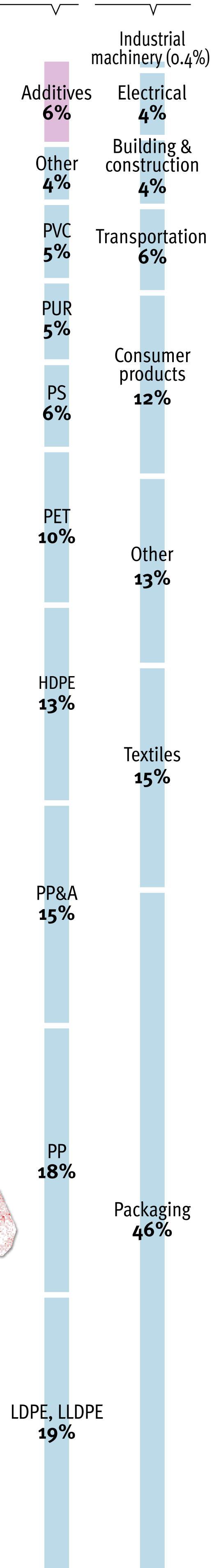
A large proportion of post-consumer plastic waste consists of plastic packaging. In the United States plastic packaging has been estimated to make up 5% of MSW (US EPA 2018). This packaging includes plastic bottles, pots, tubs and trays, plastic films (shopping bags, rubbish

Plastic waste in numbers

In 2018, of the **291 million tonnes** (Mt) of non-fibre plastic waste estimated to be generated globally →

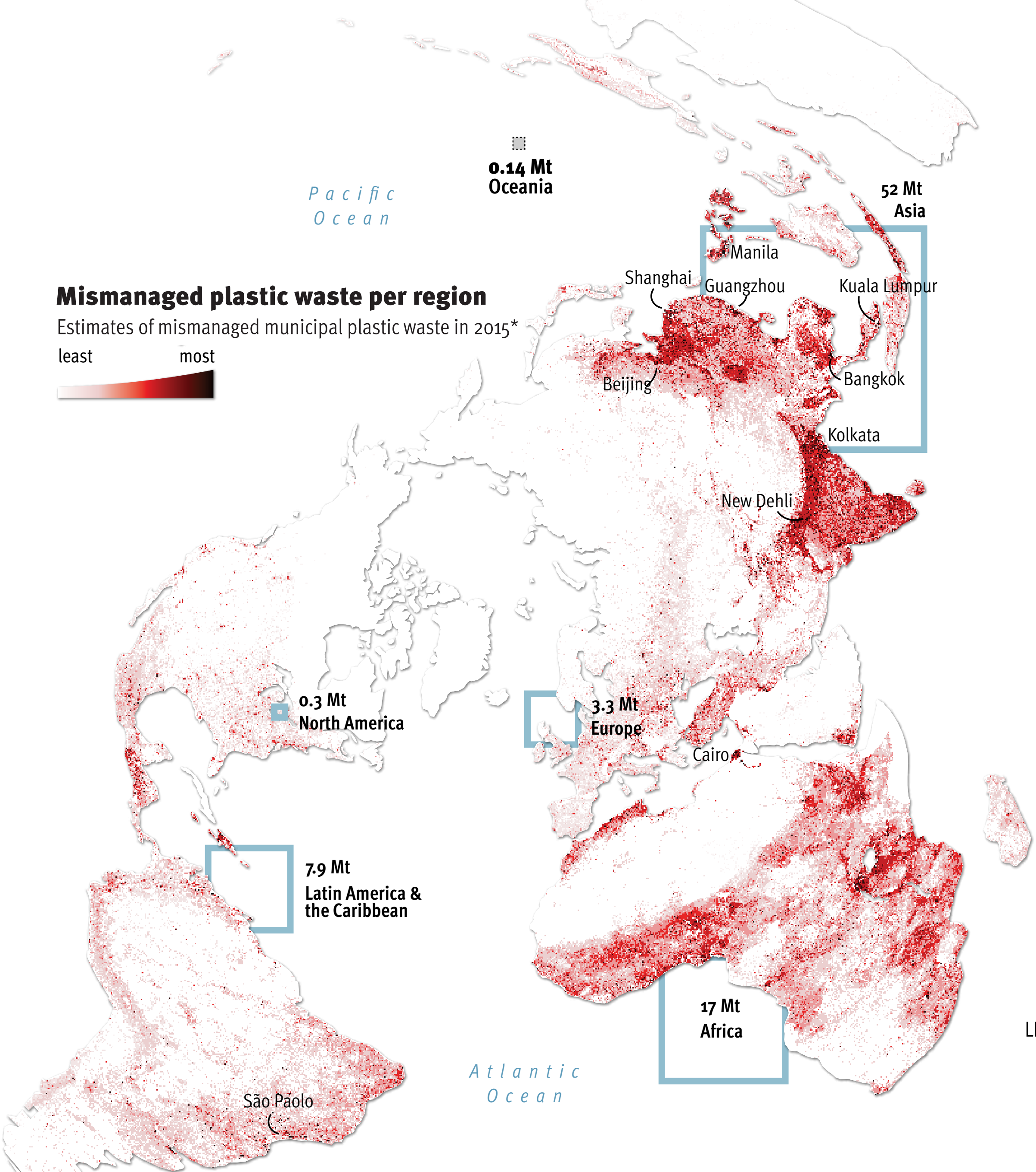


Total primary plastic waste generation (2018)



Mismanaged plastic waste per region

Estimates of mismanaged municipal plastic waste in 2015*



* Mismanaged waste is the sum of material which is either littered or inadequately disposed.

The boundaries and names shown, and the designations used on this map do not imply official endorsement or acceptance by the United Nations.

Sources: Lebreton et al. (2017), Geyer (2020). Illustration by Levi Westerveld / GRID-Arendal (2020). Research by Maria Tsakona.

bags, bubble wrap, and plastic or stretch wrap) and plastic foams (e.g. expanded polystyrene [EPS]). Plastic waste is generated in sectors including agriculture (e.g. irrigation pipes, greenhouse covers, fencing, pellets, mulch; construction (e.g. pipes, paints, flooring and roofing, insulants and sealants); transport (e.g. abraded tyres, road surfaces and road markings); electronic and electric equipment (e-waste); and pharmaceuticals and healthcare. The total amounts of plastic waste generated by these sectors is uncertain.

Global recycling rates for plastic waste have historically been low. Less than 10% of the plastic waste generated globally between 1950 and 2017 is estimated to have been recycled. Of the remainder, 14% has been incinerated while the remaining 76% has been disposed of in landfills or dumps or released into the environment, including the oceans (Geyer 2020).

Several studies have attempted to quantify plastic leakage into the environment at both national and global levels (Essel et al. 2015; Lassen et al. 2015; Velis et al. 2017; Ryberg et al. 2019; UNEP 2020). These studies highlight the difficulty of determining the sources and amounts of all plastic leakage. One global study has estimated that between 60 and 99 million tonnes of mismanaged plastic waste were produced in 2015 (Lebreton and Andrady 2019). Borrelle et al. 2020 has estimated that 19-23 million tonnes of plastic waste entered aquatic ecosystems in 2016. while the Pew Charitable Trusts and SYSTEMIQ (2020) have estimated that 9-14 million tonnes of plastic waste ended up in the oceans the same year.

Despite global efforts to reduce the generation of plastic waste, losses to the environment are predicted to increase. Modelling indicates that, without major interventions, between 23 and 37 million tonnes per year of plastic waste could enter the oceans by 2040 (The Pew Charitable Trusts and SYSTEMICS 2020) and between 155 and 265 million tonnes per year could be discharged into the environment by 2060 (Lebreton and Andrady 2019). Under a business as usual scenario, such increases would likely be attributable to a continuing rise in production of plastic products, driven by consumer demand, accompanied by insufficient improvements in waste management (Borrelle et al. 2020). As the plastic waste released into the environment already has a significant impact on ecosystems, an increase of this magnitude could have dramatic consequences.

CHAPTER 5

Sources of microplastics

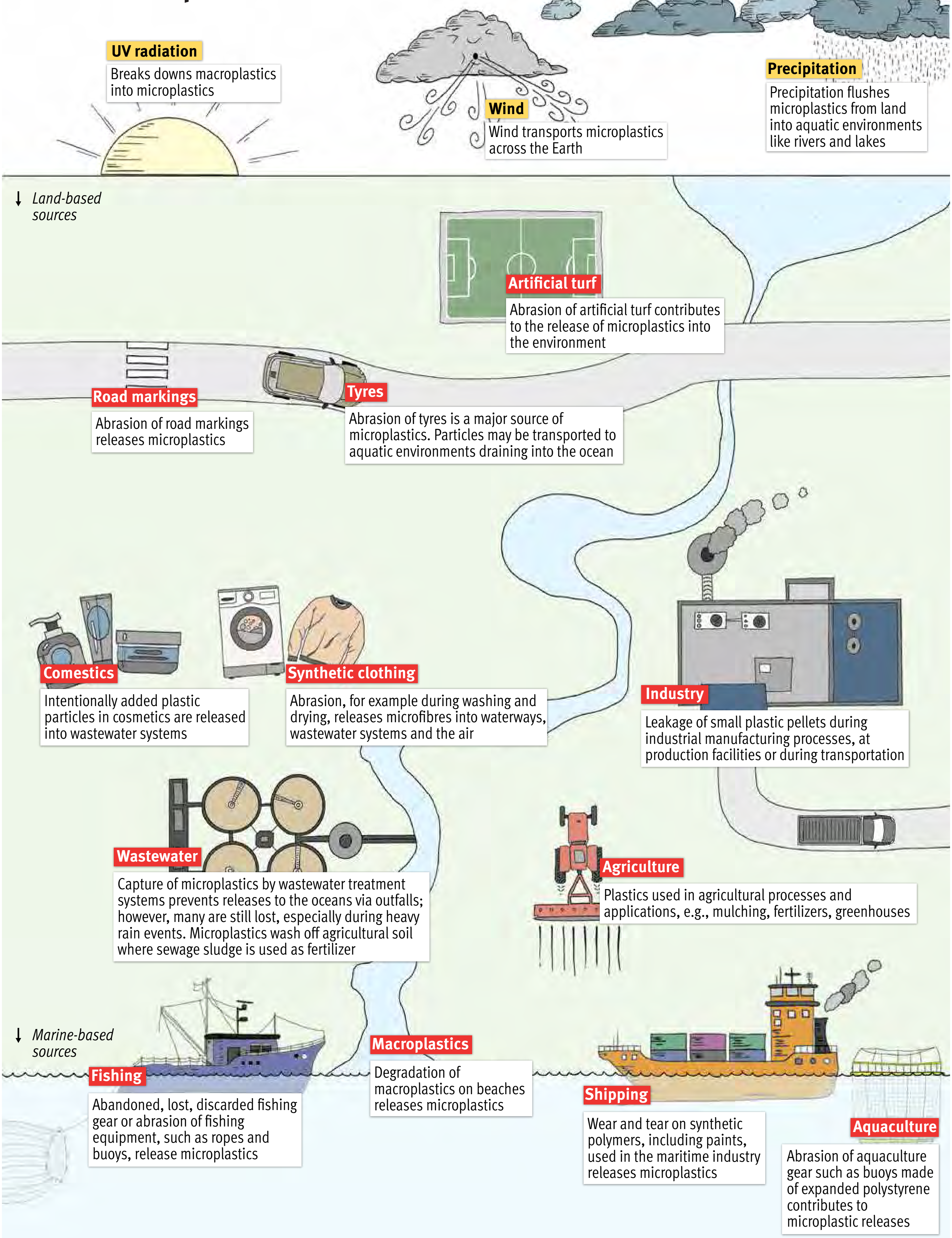
Microplastics are very small pieces of plastic commonly defined as less than 5 millimetres (mm) in size. They include nanoplastics, which are generally agreed to be less than 1 micrometre (µm) (GESAMP 2016). Microplastics exist in many forms, including fragments, fibres (referred to as “microfibres”), spheres, films and pellets. Now ubiquitous in the environment, they are present in food, water and air (UNEP and GRID-Arendal 2016; FAO 2017). There are two types of microplastics (Arthur et al. 2009): primary microplastics are manufactured for the purpose of being added to (or used in the production of) other products; secondary microplastics are created by the fragmentation and degradation of macroplastics (i.e. plastic items greater than 5 mm in size). Secondary microplastics include fibres from synthetic textiles and particles produced by tyre abrasion.

Pre-production plastic pellets (or “nurdles”) are an example of primary microplastics. These tiny pellets, which are used as feedstock in the manufacture of plastic products, can be lost during handling, spillages at production facilities, or transport (Eunomia 2018). Microbeads are another example. These spherical or amorphous microplastics are intentionally added to products including cosmetics and personal care items, fertilizers, paint, detergents, food supplements, hand sanitizers and medicinal products for various purposes (Eunomia 2018; ECHA 2019). Large volumes of microbeads can be released into wastewater systems after a product containing them has been used only once. When microbeads and other microplastics enter sewage systems, the sludge is used as fertilizer in some countries, which means agricultural soils are polluted with plastics (Selonen et al. 2020).

Most microplastics found in the environment are secondary microplastics. A major source of these microplastics is the abrasion of tyres against road surfaces. Another important source is the release of fibres from synthetic textiles during wear and tear or when they are laundered or otherwise cleaned. Microplastics are released from artificial turf during intended use or after disposal when, for example, it breaks down in landfills.

Microplastics generated on land can make their way to the oceans via household drainage, wastewater systems, street drains, poorly managed waste disposal sites, run-off from agricultural soils or transport through the air. Sea-based sources include maritime activities such as fishing, shipping and aquaculture. These activities can also result in microplastic releases due to abrasion, but the volumes released tend to be less than those from land-based sources. Microplastics are released into the marine environment from fibreglass boats (GESAMP 2015) and from fisheries and aquaculture activities. Synthetic fibres are used to make fishing gear such as ropes,

Sources of microplastics in the marine environment



Source: Waldschläger et al. (2020). Illustration by GRID-Arendal.

netting, traps, floats, buoys (often made from synthetic polymers) and lines (FAO 2017). Packaging, particularly expanded polystyrene, is a contributor of microplastics from both land and maritime activities (GESAMP 2016). Information on rates of release is not available for many of these sources.

Larger plastics that have made their way into the environment can slowly degrade or fragment into smaller pieces and eventually into microplastics. The primary causes of this breakdown are solar UV radiation and physical abrasion, which make the plastic weak and brittle over time. Embrittled plastics can release microplastics long before they themselves become small enough to be classified as microplastics (GESAMP 2015). Plastics on beaches tend to break down faster than those floating on the ocean surface, possibly due to greater exposure to the sun and to mechanical wave action. Plastics in the mid-water column and in sediments take longer to break down due to lower levels of sunlight. Algae and other growth on the surface of plastics can block sunlight, slowing down the degradation process, altering particle densities, and ultimately leading to sedimentation. However, there are as yet no reliable estimates of the rate of breakdown of plastics under specific conditions. Plastics that are biodegradable in commercial facilities are unlikely to degrade in ocean conditions, where average temperatures and oxygen levels are far lower (GESAMP 2016).

Once microplastics enter the marine environment, they are extremely difficult and expensive to remove. It is therefore important to prevent the generation of microplastics by, for example, banning the use of microbeads in many products. In the EU it is estimated that banning the intentional addition of microplastics to cosmetics, detergents, paints, polish and coatings, among others, would reduce emissions of microplastics by about 400,000 tonnes over 20 years (ECHA 2019). Losses of plastic pellets, flakes and powders to the environment from manufacturing processes can be reduced through the implementation of voluntary programmes such as Operation Clean Sweep, a set of best practices designed by industry to prevent such losses including during transport (PlasticsEurope 2019; American Chemistry Council 2020).

Capture devices can prevent microplastics entering the environment, including the oceans. Clothes can be dried in the sun; where this is not an option, however, installing lint traps in dryers (as well as filters in washing machines) can capture microfibres. Wastewater and sewage treatment plants can filter out microplastics with up to 90% success rates, but these systems are expensive and are not common in many countries (GESAMP 2016). Heavy rain events can overwhelm such capture systems, leading to significantly greater flows of microplastics into the marine environment including from street run-off.

Alternative product design can also be considered in the suite of prevention strategies. In some cases (e.g. vehicle tyres and brakes) wear and tear would be difficult to eliminate entirely, as abrasion contributes to the functioning of the product. Studies have shown that the breakdown of expanded polystyrene (EPS) buoys used in aquaculture accounted for over 90% of microplastics found on beaches in the Republic of Korea (FAO 2017). Conventional EPS buoys have been redesigned with a hard plastic coating to prevent losses. These buoys are widely used in Japan (NOWPAP 2015). Eco-labelling can influence consumer choices. In Europe the rate of abrasion is to be included on tyre labels (European Parliament News 2020). Material and process innovation can reduce the amount of microfibres released from textiles (Ellen McArthur Foundation 2017). To promote such efforts, microplastics could be considered in regulations and legislation addressing air, water and soil quality.

CHAPTER 6

Sources of plastic waste in the marine environment – packaging

Plastic packaging is everywhere. It envelops many of the products we buy at the store and almost all those delivered to our front door. Since the 1950s plastic packaging has replaced paper, glass, metal and other reusable materials. It is estimated that 3.4 billion tonnes of plastic packaging were introduced into our lives between 1950 and 2017 (Geyer 2020).

Efforts to replace plastic packaging with more sustainable alternatives need to consider the advantages of plastics and potential trade-offs along the complete life cycles of products, together with all potential environmental impacts (UNEP 2021). Today packaging is the largest use of plastic resins, accounting for 36% (158 million tonnes) of the world's total plastic production by mass (Geyer 2020). Plastic packaging is used in the commercial, retail, household, tourism and agricultural sectors. Consumption rates vary among and within countries, with developing countries generally less reliant on packaging. In China annual plastic packaging consumption is approximately 14 kg/capita (WWF 2020); in Europe the rate is much higher, averaging 174 kg/capita (Eurostat 2020).

Most plastic packaging is disposed of within a relatively short time. Discarded packaging accounts for 46%

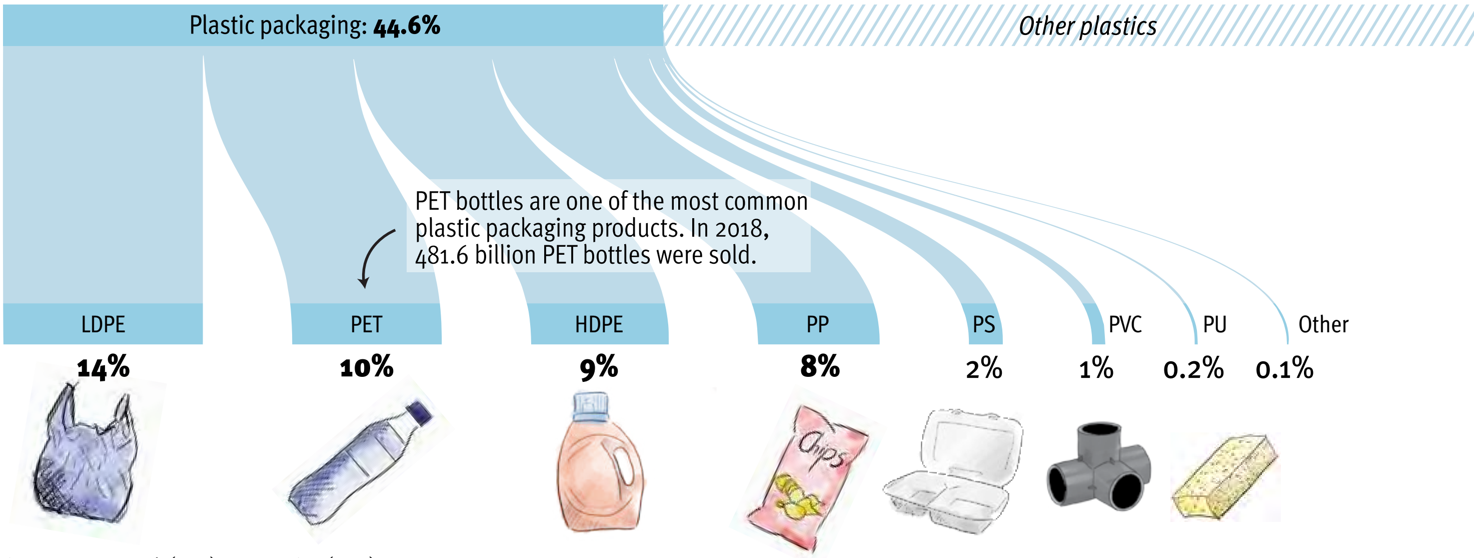
(158 million tonnes) of total annual plastic waste generation (Geyer 2020). Most plastic packaging waste is estimated to come from household waste. According to a 2010 survey by the Waste and Resources Action Programme (WRAP), 73% of all plastic packaging waste in the United Kingdom came from households (WRAP 2010). Waste plastic packaging makes up a considerable portion of collected aquatic litter (15.9% in the oceans and 74.5% in rivers) (Schwarz et al. 2019).

The convenience and low cost of plastics are the main reasons for their continuously increasing use. Plastic packaging can keep food fresh longer, prevent food waste, and provide consumers with a greater variety of food. In addition, goods in plastic packaging can be easily transported and distributed. In this way plastic packaging makes a valuable contribution to global food security. In certain situations replacing plastic packaging may not be either viable or sustainable. However, efforts are ongoing to reduce reliance on plastic packaging without compromising food security (Guillard et al. 2018).

Industry and businesses in the packaging sector have become a focus for the anti-plastic pollution movement. For

Plastic packaging consumption

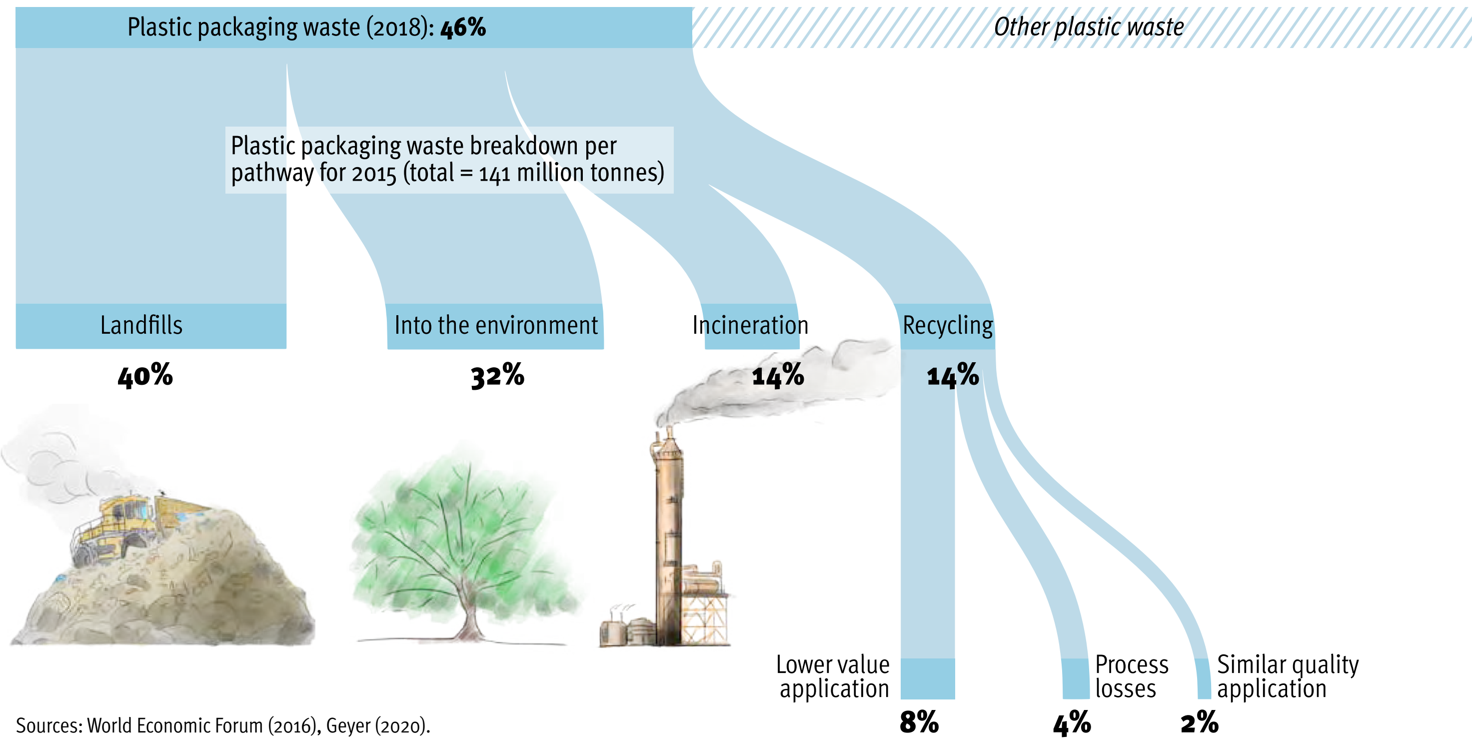
% of total plastic consumption, and per polymer type (2002-2014)



Sources: Geyer et al. (2017), Euromonitor (2019).

Plastic packaging waste generation

% of total plastic waste, and end of life fate



Sources: World Economic Forum (2016), Geyer (2020).

7 of the most common* marine litter items found in coastal areas are plastic packaging

* by quantity of pieces found.
Source: Ocean Conservancy (2019). Results from the 2018 International Coastal Cleanup. Item 1 was cigarette butts, item 3 was straws and stirrers, and item 4 was plastic cuttlery.

example, the "Break Free From Plastic" brand audit found that products from just three companies accounted for 14% of branded plastic pollution at sampling sites in 51 countries (Greenpeace Philippines 2019). Owing to legislative requirements, a growing focus on companies as polluters and changing consumer expectations, some efforts to reduce plastic waste from packaging are underway. They include greater reliance on reusable packaging and higher recyclable content. However, progress is slow due to the unstable market for secondary raw materials and uncertainties about alternative materials.

Many governments are scaling up their efforts to phase out single-use plastic packaging and to manage plastic packaging waste in an environmentally sound manner. A number of countries have legislation to ensure that plastic packaging waste collected from households is sorted, reprocessed, compounded, and reused or recycled. There are also bans on single-use plastic food packaging in many countries. Such bans need to be assessed against potential threats to food and water safety, particularly in developing countries where food packaging can significantly increase the safety of handling and storage (e.g. in cases where bottled water appears to be the safest option).

A key step in combating plastic waste is to ensure that companies which produce plastic packaging play a leading role in its reuse or recycling, for example through schemes like extended producer responsibility (EPR). An increasing number of companies are willing to support such approaches, for example in the beverage industry (Robbins 2020).

CHAPTER 7

Sources of plastic waste in the marine environment – agriculture

Plastic products are used extensively in agriculture, for example to increase crop yield and improve the efficiency of water and agrichemical use. "Agriplastic" products include films to cover greenhouses and tunnels, mulch to cover soil (e.g. to suppress weeds, conserve water, increase soil temperature and aid fertilizer application), shade cloth, pesticide containers, seedling trays, protective mesh and irrigation tubing (Scarascia-Mugnozza et al. 2012). The polymers most commonly used in these products are low-density polyethylene (LPDE), linear low-density polyethylene (LLDPE), polypropylene (PP) and polyvinyl chloride (PVC) (Briassoulis 2013; PlasticsEurope 2019).

The total amount of plastics used in agriculture is difficult to quantify. A 2012 study reported that almost 6.5 million tonnes per year were consumed globally (Scarascia-Mugnozza et al. 2012) while a later study estimated that global demand in 2015 was between 7.3 million and 9 million tonnes (Cassou 2018). In China the amount of plastic mulch used increased between 1981 and 2014 from 0.11 million tonnes to 1.4 million tonnes (which would cover approximately 18.14 million hectares) (Liu et al. 2014; World Agriculture 2017). It is estimated that 708,000 tonnes of plastics were used in livestock and crop production in the EU in 2019 (not counting plastic packaging for agricultural products, which represented about 1 million tonnes); 75% consisted of plastic films, mainly including plastic mulch, greenhouse covering, low tunnels and bale wrapping for silage preparation (EIP-AGRIE Focus Group 2021).

Widespread use of plastic mulch and lack of systematic collection and management have led to the generation of large amounts of mulch residue. Weathering and degradation eventually cause the mulch to fragment. Studies indicate that these fragments and larger pieces of plastic accumulate in soil. Mulch residue has been measured at levels of 50 to 260 kg per hectare in topsoil in areas where the mulch has been used for more than 10 years (Liu et al. 2014; Huang et al. 2020), which confirms that mulching is a major source of both microplastic and macroplastic contamination of soil.

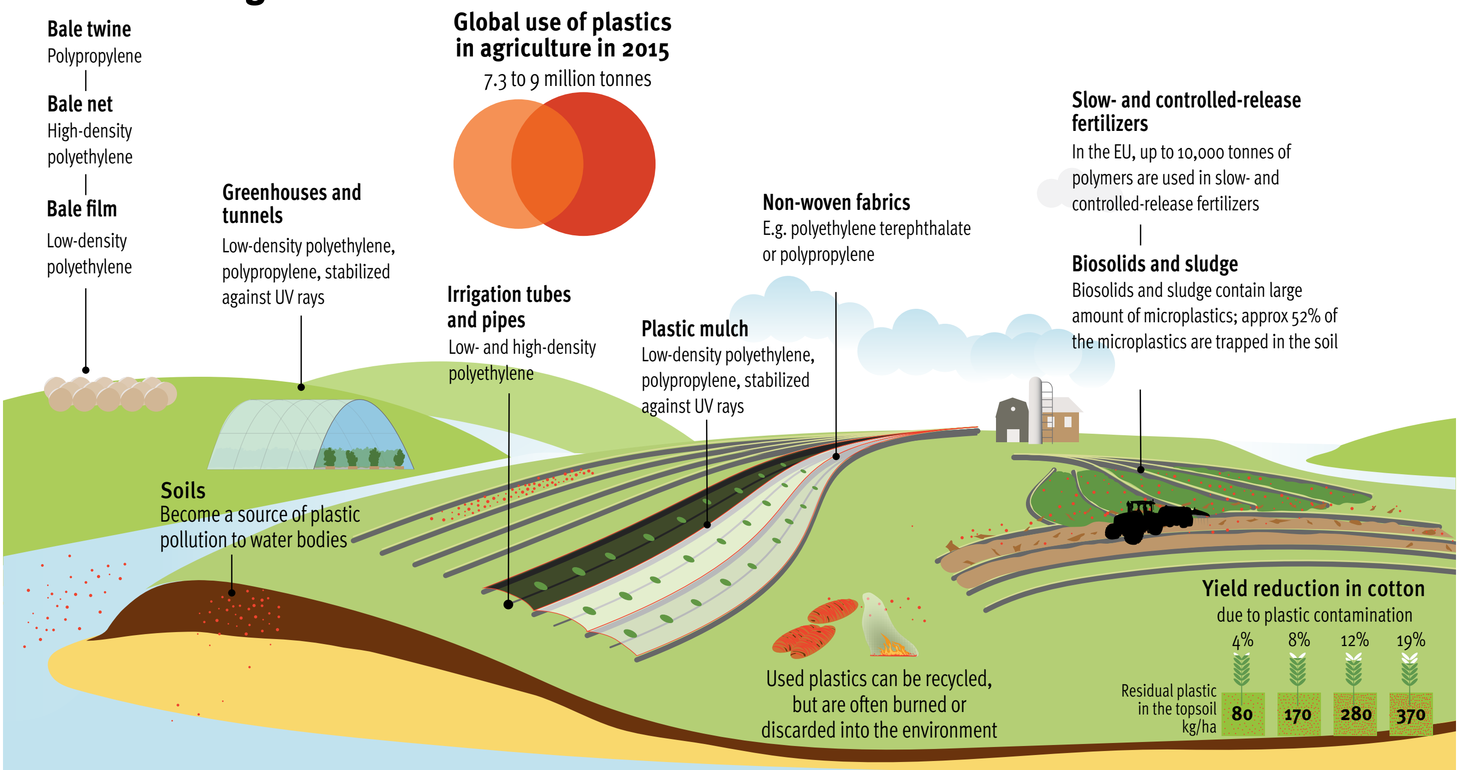
Agricultural plastics, especially plastic films, are not easy to recycle because of high contamination levels (up to 40-50% by weight contamination by pesticides, fertilizers, soil and debris, moist vegetation, silage juice water, and UV stabilizers) and collection difficulties (Kasirajan and Ngouajio 2012). Therefore, they are often buried or abandoned in fields and watercourses (Vox et al. 2016) or burned (Scarascia-Mugnozza et al. 2012; Briassoulis 2013). These disposal practices lead to soil degradation and can result in contamination of soils and leakage of microplastics into the marine environment (e.g. Li et al. 2018; SAPEA 2019; Hurley et al. 2020) as a result of precipitation run-off and tidal washing (e.g. Ng et al. 2018). In addition, additives in residual plastic film (such as UV and thermal stabilizers) may have deleterious effects on crop growth, soil structure, nutrient transport and salt levels. There is a risk that plastic mulch will deteriorate soil quality, deplete soil organic matter stocks, increase soil water repellence and emit greenhouse gases (Steinmetz et al. 2016). Furthermore, microplastics released through fragmentation of agricultural plastics can absorb and concentrate contaminants capable of being passed up the trophic chain (Galloway and Lewis 2016).

The application of biosolids from sewage sludge and compost can introduce microplastics to soils. This adds to the burden of microplastics from other sources (e.g. the atmosphere). Approximately half the sewage sludge in Europe and North America is applied to agricultural land. In Europe it has been estimated that for every million inhabitants 113 to 770 tonnes of microplastics are added to agricultural soils each year (Nizzetto et al. 2016a).

Microfibres from synthetic textiles are another type of plastic soil contamination (Henry et al. 2019). According to Zhang and Liu (2018), 100% of agricultural soil samples from southwestern China contained plastic particles, 92% of which were microfibres. Sources of microfibres likely included string or twine, as well as irrigation water in which clothes had been washed (Zhang and Liu 2018).

Most plastics used in agriculture have a homogeneous composition, making them valuable to recyclers if collected and managed appropriately. Several EU Member States have adopted EPR schemes for agricultural plastics which include establishing waste collection and recycling programmes. In

Plastics in agriculture

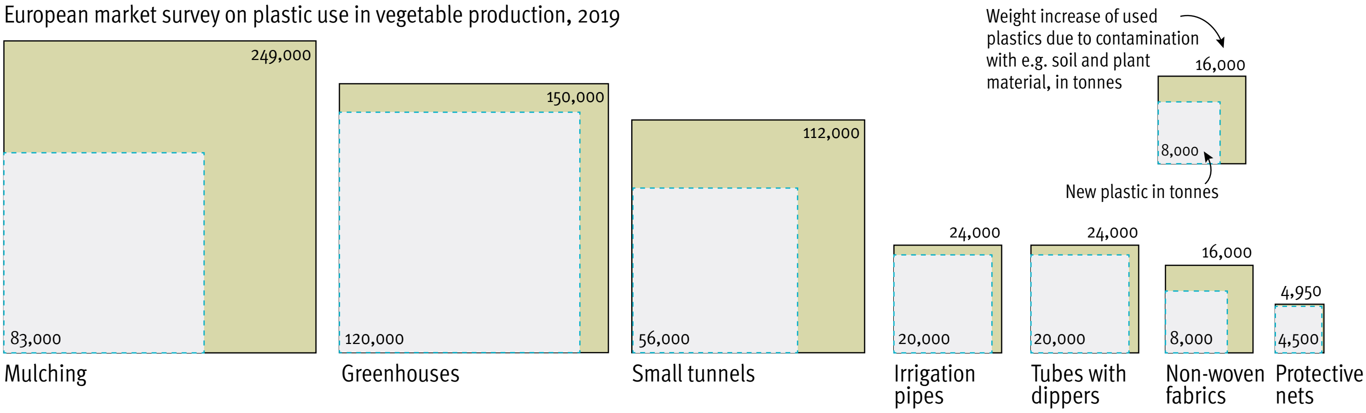


Sources: Scarascia-Mugnozza et al. (2012), Briassoulis et al. (2013), World Agriculture (2014), Nizzetta et al. (2016a), Cassou (2018), EIP-AGRIE Focus Group (2021).

Illustrated by GRID-Arendal/Studio Atlantis (2021)

Contamination by plastics used in agriculture

European market survey on plastic use in vegetable production, 2019



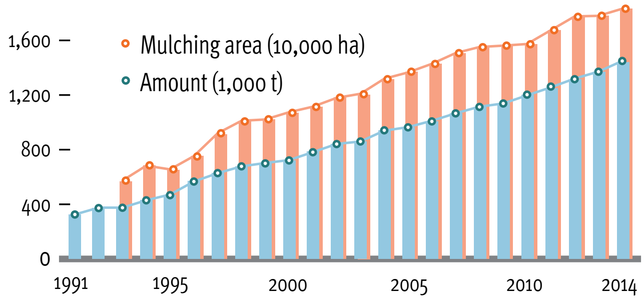
Source: EIP-AGRIE Focus Group (2021). Illustrated by GRID-Arendal (2021).

2017 the collection rate for agricultural plastic waste in the EU reached around 60% (Plasteurope 2017). In addition, several production standards for agricultural films and nets have been introduced to comply with mechanical and physical requirements in order to reduce the potential for fragmentation, enhance collection and minimize environmental impacts (Scarascia-Mugnozza et al. 2012).

Biodegradable mulch films (see Chapter 19) are being developed to replace widely used soil contaminating polyethylene (PE) films (Bioplastics Magazine 2019). However, production and development of biodegradable mulch films is at an early stage, with high production costs and several other barriers to large-scale use. In Spain, for example, biodegradable plastic films are 25-188% more expensive than PE films (Mari et al. 2019). Moreover, the general claim of biodegradability is unlikely to be valid unless accompanied by details about the conditions under which it can be achieved (Albertsson and Hakkarainen 2017).

Increase in use of plastic film mulch

China, 1991 to 2014



Sources: Liu et al. (2014), World Agriculture net (2014). Illustrated by GRID-Arendal (2021).

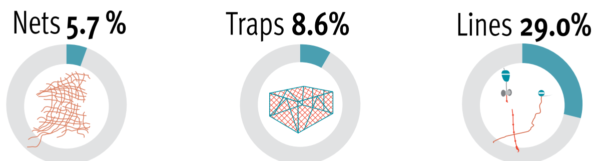
CHAPTER 8

Sources of plastic waste in the marine environment – fisheries and aquaculture

In 2018 global fish production exceeded 179 million tonnes. While capture fisheries production has remained relatively static in the last few years, aquaculture production has grown. It currently represents nearly half of total fish production. The global fishing industry has a fleet of more than 4.5 million vessels and employs nearly 60 million fishers, of which 65.5% (39 million) work in capture fisheries and the rest in aquaculture (FAO 2020). Despite increasing research aimed at quantifying the sources of marine litter, determining the contributions from fisheries and aquaculture remains a challenge (GESAMP 2020).

Abandoned, lost, or otherwise discarded fishing gear (ALDFG) includes netting, mono/multifilament lines, hooks, ropes, floats, buoys, sinkers, anchors, metallic materials and fish aggregating devices (FADs) made of non-biodegradable materials such as concrete, metal and polymers (MEPC 2020; FAO ISSCFG 2013). It has been estimated that global fishing gear losses each year include 5.7% of all fishing nets, 8.6% of all traps and 29% of all lines used (Richardson et al. 2019). ALDFG can have serious impacts on marine organisms through entanglement and ingestion.

Fishing gear lost in the ocean in 2017

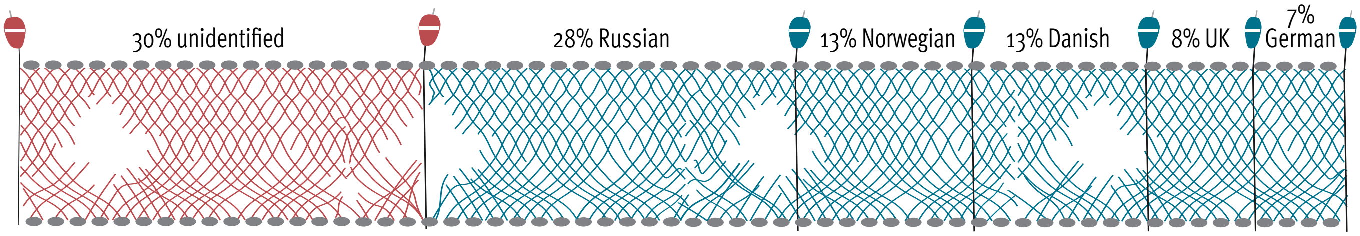


Not representative of all fisheries in all geographic conditions

Source: Richardson et al. (2019a) Illustrated by GRID-Arendal (2021).

Traceability of lost fishing gear in the Arctic

Beach survey from Svalbard, Norway, 2019



Source: Falk-Andersson (2019). Illustrated by GRID-Arendal (2021).

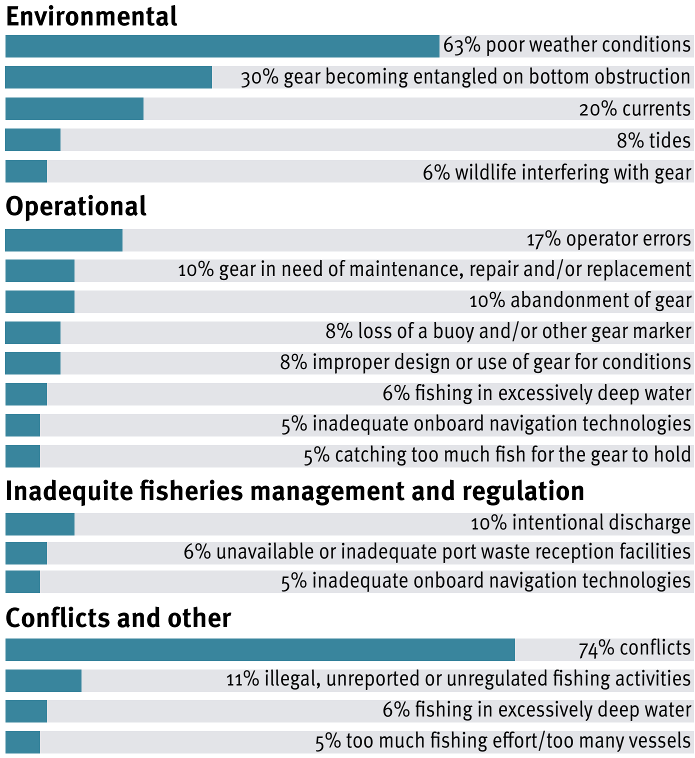
The potential for fishing gear to become ALDFG depends on a number of factors (UNEP 2020). For example:

- Environmental factors are mostly related to seafloor topography and obstructions, although tides, currents, waves, winds, and interaction with wildlife are also important.
- Operational losses and operator errors can occur even during normal fishing operations.
- Problems such as inadequate fisheries management and regulations that do not include adequate controls can hamper collection of ALDFG (e.g. there may be poor access to collection facilities).
- Gear loss resulting from conflicts primarily occurs (intentionally or unintentionally) in areas with high concentrations of fishing activities, leading to gear being towed away, fouled, sabotaged or vandalized. Passive and unattended gear such as pots, set gillnets and traps are particularly prone to conflict damage. In the Arctic, conflicts are the most common reason for lost gear (Langedal et al. 2020).

Regional fishing practices differ, while corresponding gear diversity makes extrapolations and global estimations difficult (MEPC 2020). Depending on the circumstances, fishers may attempt to retrieve lost gear since replacement costs can be high (Lively and Good 2019). However, recovery is not always possible even in jurisdictions that have well-developed systems for doing so. In Norway, for example, where all commercial fishing vessels over 28 metres are required to report the location and nature of gear loss to aid retrieval operations, a significant amount is not recovered. A recent study estimated that the Norwegian commercial fishing industry loses around 380 tonnes of plastic fishing gear annually (Deshpande et al. 2020).

Fishing gear in use can contribute to releases of microplastics in the oceans. The greatest source is probably netting used in benthic dredges and trawls and ground ropes, which are abraded as they are dragged across the seabed (FAO 2017).

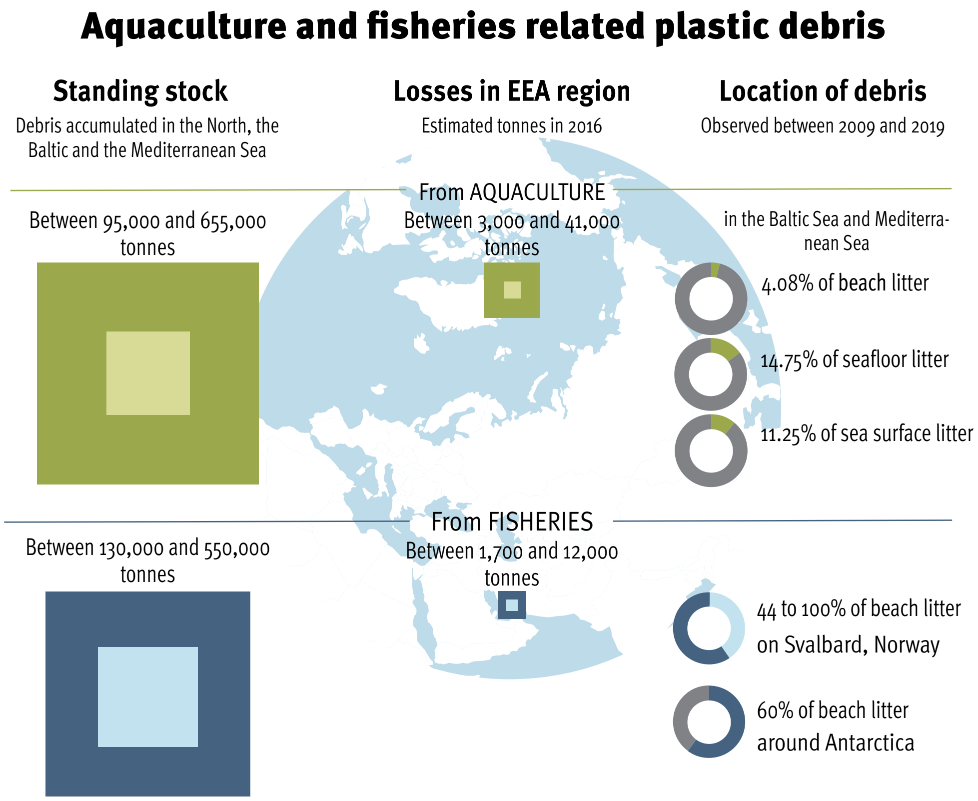
Common causes of abandoned, lost or otherwise discarded fishing gear



The numbers show the percentage of studies reporting the listed specific causes of ALDFG. Based on a review of 176 reports over which 58% reported causes for ALDFG.

Source: MEPC (2020). Illustrated by GRID-Arendal (2021).

Aquaculture produces a range of marine debris, depending on the product and location. The most frequently documented type of plastic is expanded polystyrene (EPS), used extensively in floats and sea cage collars (MEPC 2020). Other common waste items include cage nets and plastic harvest bins (Huntington 2019). A review of aquaculture as a source of marine litter in the North, Baltic and Mediterranean Seas identified 64 different items, 19 of which were unique to aquaculture (Sandra et al. 2020). Estimates of the amount of aquaculture waste entering the oceans vary widely, depending on the methodologies used. For example, in the European Economic Area loss estimates have varied from a low of 3,000 tonnes to 41,000 tonnes per year (Sherrington et al. 2016).



Sources: Sherrington et al. (2016), Bergmann et al. (2017), Huntington (2019), MEPC (2020), Sandre et al.(2020), Waluda et al. (2020). Illustrated by GRID-Arendal (2021).

CHAPTER 9

Transboundary movements and environmentally sound management of plastic waste

For many decades, millions of tonnes of plastic waste have been shipped across borders as part of the global waste trade. From the 1990s until 2011 transboundary movements of plastic waste steadily increased. It is estimated that in 2016 almost half the plastic waste recycled (14.1 million tonnes) was not processed in-country, but exported by 123 countries to other locations (Brooks et al. 2018).

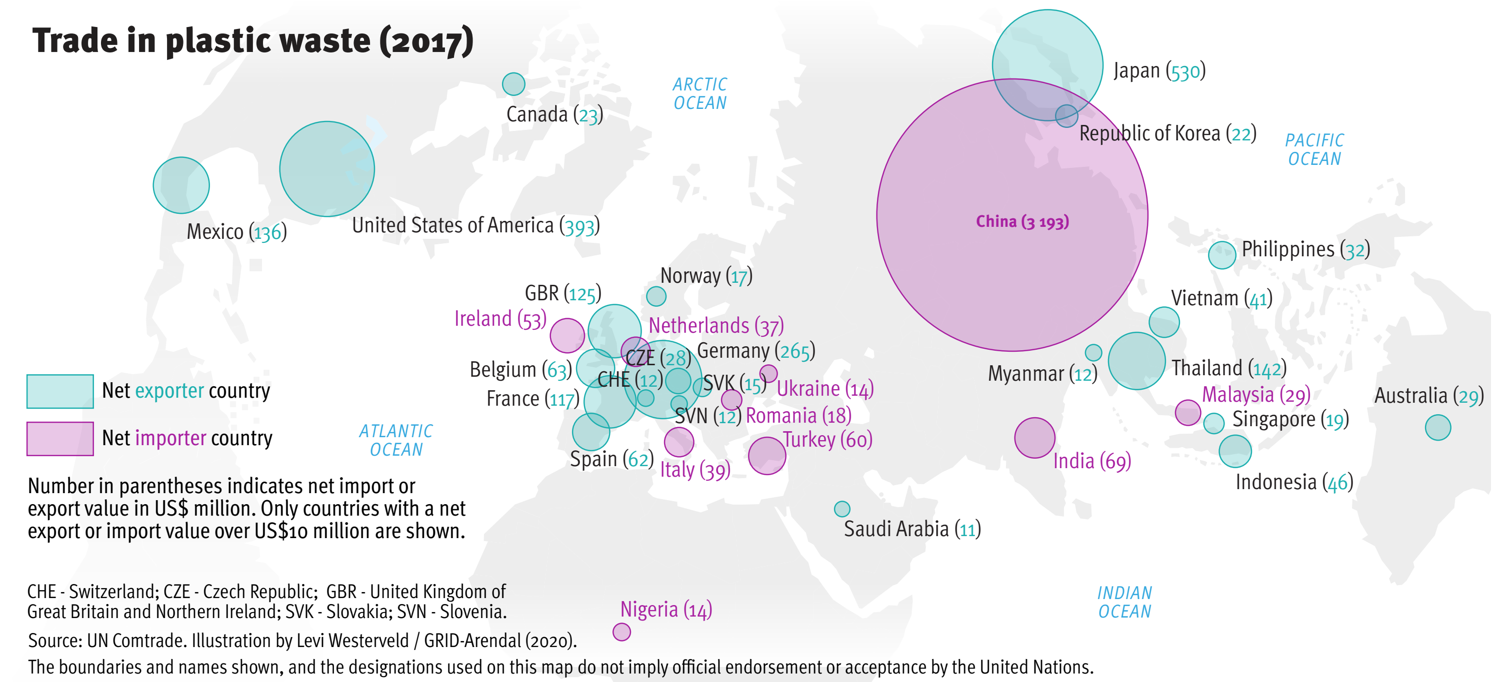
Prior to a change of policy in 2013, China was the world's main plastic waste recipient, importing almost 50% of the plastic waste exported globally since 1992 (Brooks et al. 2018). Recycled plastic has been used extensively in manufacturing in China, and imported plastic waste was predominantly processed in an informal sector that provided low-technology processing services (Velis 2014; Rucevska et al. 2015). High-income countries such as Germany, Japan, the United Kingdom and the United States were the top plastic waste exporters (UN Comtrade 2021).

In 2013 China began to implement policies, such as the Green Fence Strategy, designed to restrict imports of poor quality waste and halt illegal imports (Balkevicius et al. 2020). In 2018 China banned plastic waste imports, which had an immediate impact on the global plastic waste trade. By 2019 it had fallen by 46%, but new locations for overseas recycling and other disposal operations were opening up. India, Malaysia, the Republic of Korea, Thailand and Viet Nam have emerged as contenders (UNCTAD 2020; UN Comtrade 2021). The destabilized market has seen a sharp increase in illegal waste shipments entering Southeast Asia (Interpol 2020). Governments including those of Indonesia, Malaysia and Thailand reacted swiftly to curtail illegal plastic waste imports by reinforcing border controls (GRID-Arendal 2019). With increased control of imports, repatriation of illegal containers is occurring although this remains a long and challenging process (Interpol 2020). Consequently, plastic waste containers are accumulating in ports in Southeast Asia (Interpol 2020).

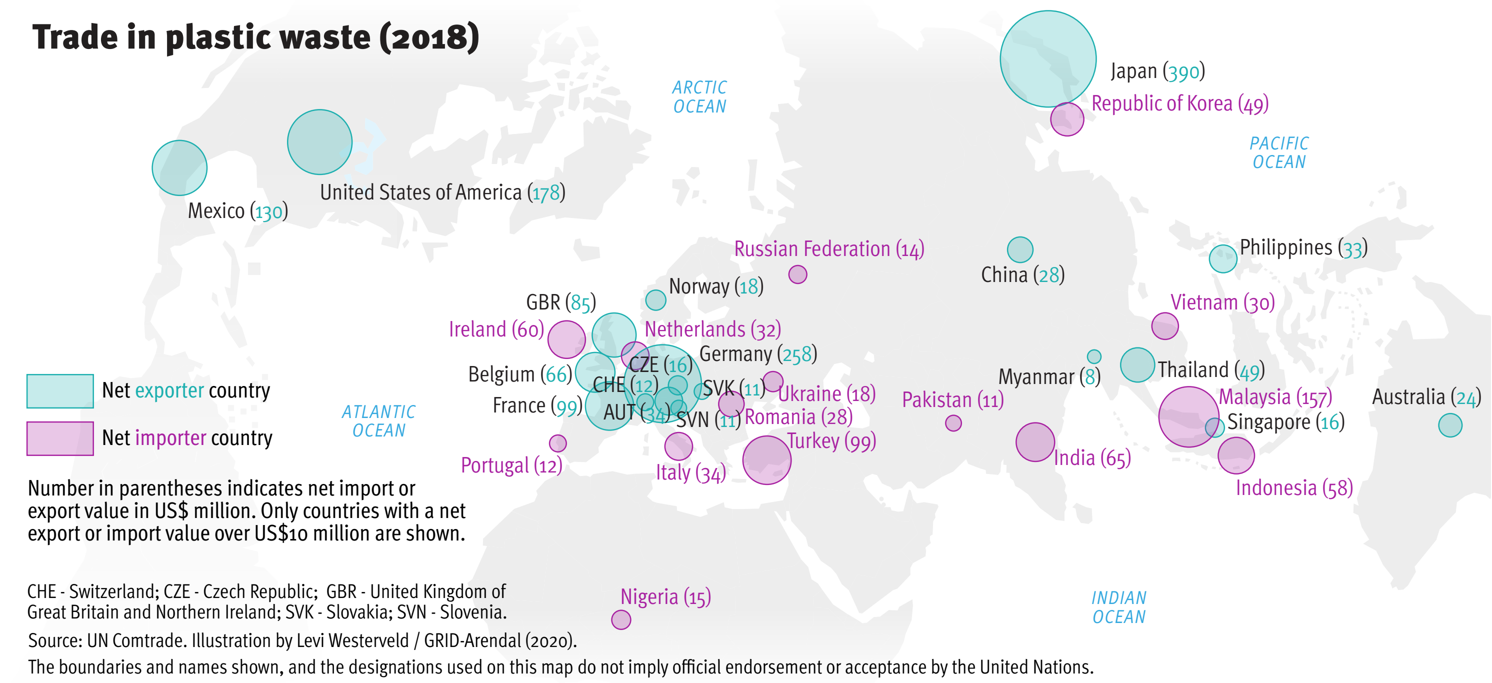
High recycling targets and shortages of domestic recycling capacities, along with economic benefits, still drive the offshore plastic waste trade. According to a recent study, Asia, Europe and North America continue to be the main trading regions although the amount of waste being transported has decreased dramatically (Wang 2020). Reflecting the growing challenges of intercontinental trade, intraregional trends have been observed. In Europe, for example, countries like the Czech Republic, Poland, Romania and Turkey have emerged as recycling destinations owing to low waste recycling costs (Interpol 2020; Selmer-Andersen 2020; UN Comtrade 2021). Exports to Africa, the Middle East and South America have increased in the past decade, but are still relatively small (Wang et al. 2020). Over time these regions are expected to become more important. The COVID-19 pandemic has temporarily shrunk global trade in plastic waste, due among other reasons to reduced activity at waste management facilities, interruptions of shipping routes, and low oil prices which have reduced the cost of virgin plastic and made recycled plastics less attractive financially (Iacovidou and Ebner 2020).

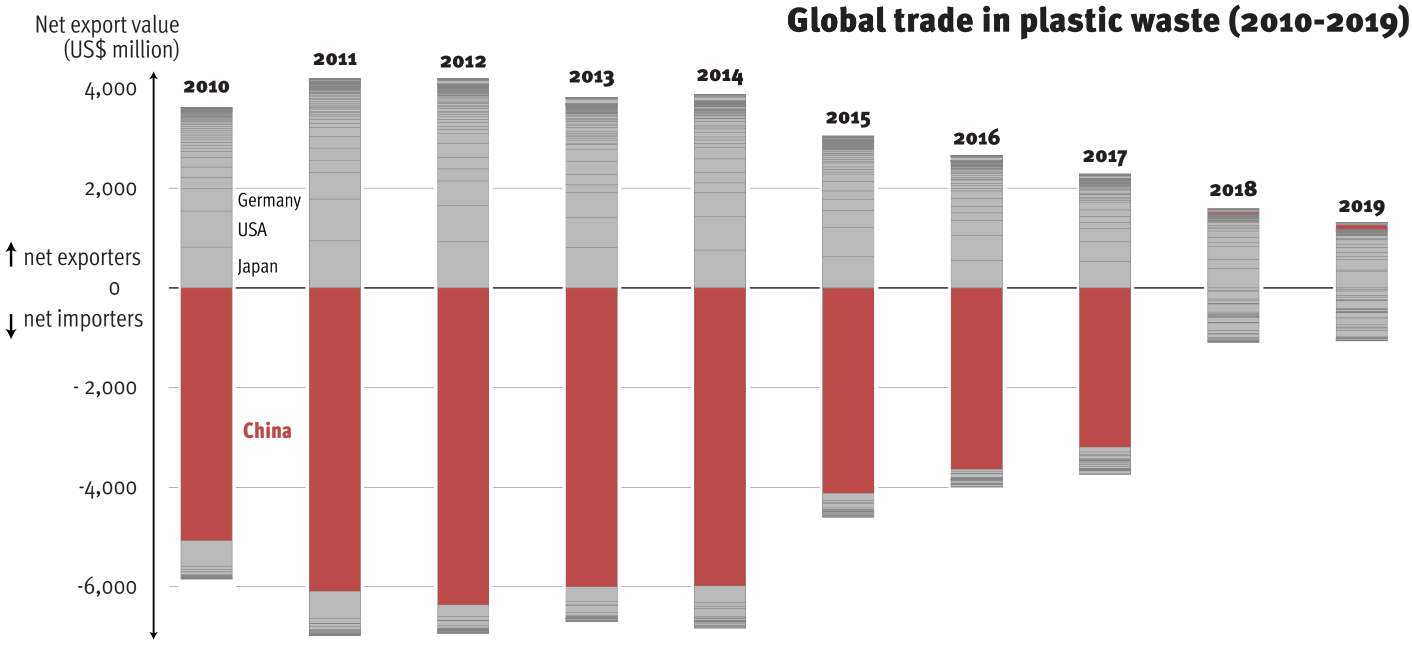
To enhance controls on transboundary movements of plastic waste and clarify how the Basel Convention applies to such wastes, Parties to the Convention have agreed on amendments which came into effect on 1 January 2021. These amendments clarify which types of plastic waste are considered hazardous and which ones, although not hazardous, still require special consideration and are subject to the control procedure for exports, transit and imports of wastes under the Basel Convention (see Chapter 22).

Trade in plastic waste (2017)



Trade in plastic waste (2018)





Source: UN Comtrade. Illustration by Levi Westerveld / GRID-Arendal (2020).

Under the Convention, any Party can decide to prohibit imports of hazardous plastic waste and, since 1 January 2021, of mixed plastic wastes falling under Annex II and requiring special consideration. States of export that are Parties to the Convention need to make arrangements to ensure environmentally sound management of their wastes – either through alternative importers or by increasing their own capacity, taking into account any decision by Parties to prohibit the import of plastic wastes covered by the Convention (Huang et al. 2020).

CHAPTER 10

Natural disasters and plastic waste

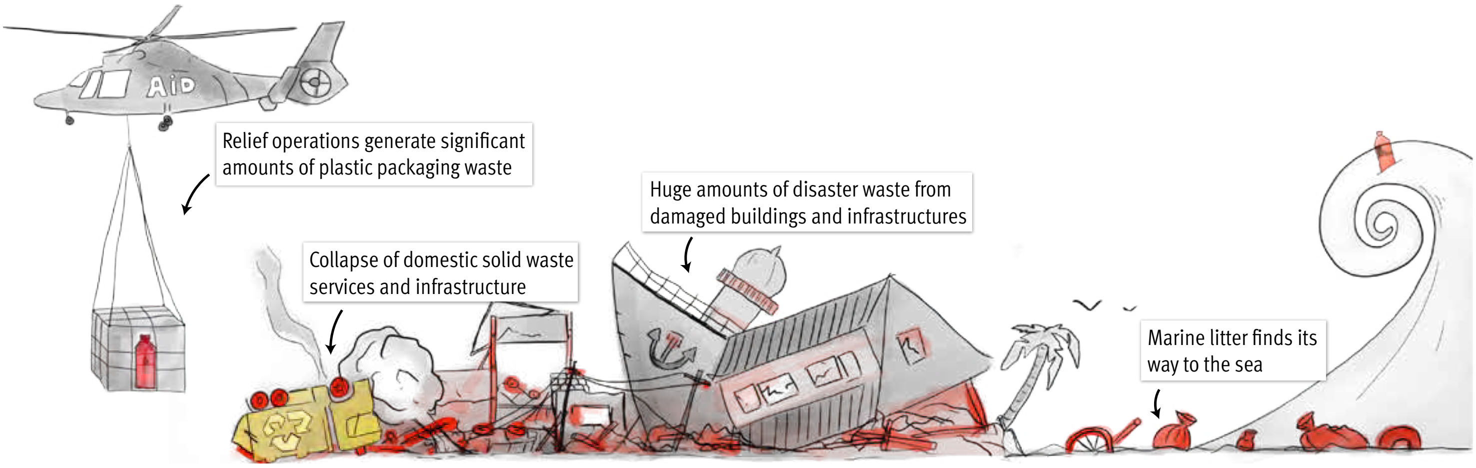
During emergencies such as natural disasters and armed conflicts more waste may be produced, while waste management is given low priority compared with other services. Existing waste management services and infrastructures can be disrupted, leaving communities with unmanaged waste and increased littering. Under these circumstances human health and the environment are often negatively impacted (UNEP/OCHA 2011).

Natural disasters (e.g. earthquakes, tsunamis, hurricanes) have the potential to generate a significant amount of waste within a short period. Waste management systems can be out of action or curtailed, often requiring considerable time and funding to restore. For example, the tsunami in Japan in 2011 produced huge amounts of debris: estimates of 5 million tonnes of waste were reported by the Japanese Ministry of the Environment (2012). Some of this waste (mostly plastic and Styrofoam [extrudred polystyrene foam, or XPS]) washed up on the coasts of Canada and the United States in late 2011 (Alaska Department of Environmental Conservation 2012; Hipfner et al. 2018). Along the west coast of the United States, this increased the amount of litter by a factor of 10 and may have transported alien species (Murray et al. 2018). Storms are also important generators of plastic litter. Lo et al. (2020) reported a 100% increase in the amount of microplastics on beaches surveyed following a typhoon in Hong Kong, China in 2018.

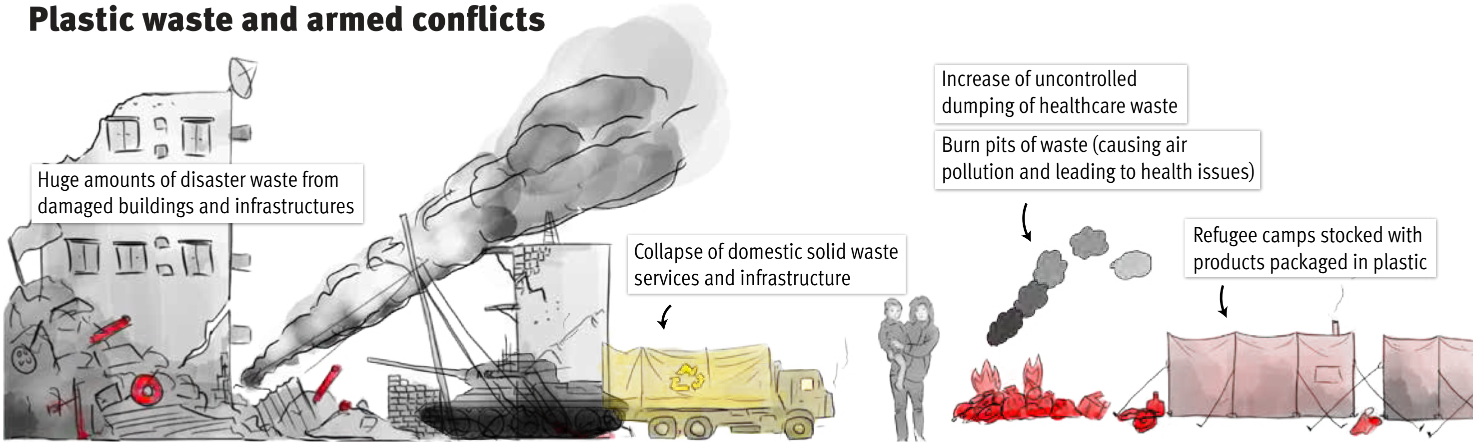
A significant amount of plastic waste can be produced during disaster relief operations (UNEP 2019). Following the 2010 earthquake in Haiti, the generation of waste from relief operations was referred to as a "second disaster". The United States military reported that millions of water bottles and XPS food packages were distributed although there was no operational waste management system (UNEP/OCHA 2011). Over 700,000 plastic tarpaulins and 100,000 tents were required for emergency shelters. The increase in plastic waste, combined with poor disposal practices, resulted in open drainage channels being blocked, increasing the risk of disease (UNEP/OCHA 2011).

Conflicts can result in large-scale displacement of communities. People living under these conditions are often provided with minimal waste management facilities. Burn pits are widely used to dispose of mixed wastes, including plastics. Air pollution can lead to respiratory and other

Plastic waste and natural disasters



Plastic waste and armed conflicts



illnesses (TRWN 2015). For example, Sahrawi refugees have been living in five camps near Tindouf, Algeria for nearly 45 years. As waste collection services are underfunded and there is no recycling facility, plastics have flooded the camps' streets and surroundings (UNHCR 2016). In contrast, the Azraq camp in Jordan for refugees from Syria has waste management services; of 20.7 tonnes of waste produced per day, 15% is recyclable (World Vision 2019).

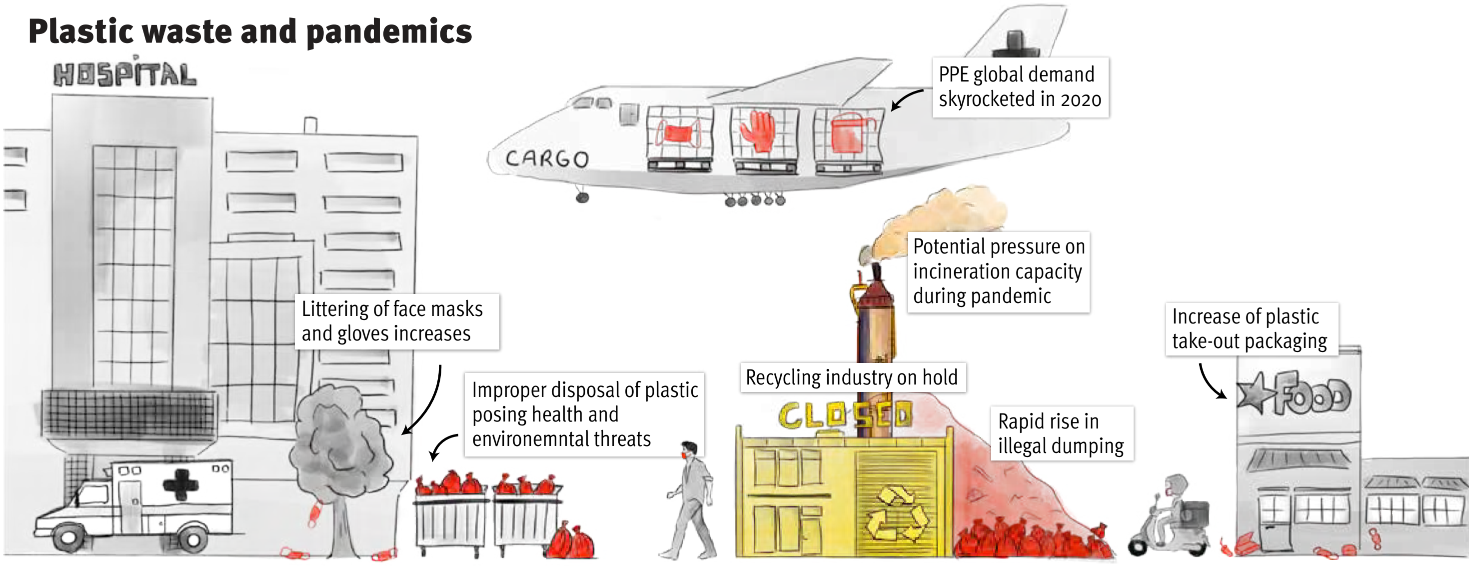
CHAPTER 11

The COVID-19 pandemic and plastic waste

The coronavirus disease (COVID-19) pandemic was declared by the World Health Organization (WHO) at the end of January 2020 (WHO 2020). The pandemic has led to an increase in the production of single-use personal protective equipment (PPE), such as disposable plastic face masks, gloves and gowns, and certain types plastic packaging (EEA 2021). WHO reported a 40% increase in the use of disposable PPE for healthcare professionals. If the global population adhered to a standard of one disposable face mask per day, it is estimated that monthly consumption (and waste) would amount to 129 billion masks and 65 billion gloves (Prata 2020). Millions of potentially contaminated masks, gloves and antiseptic wipes have escaped into the environment because of street littering. WWF has estimated that as many as 10 million face masks per month could enter the environment if just 1% of the masks discarded are improperly managed (WWF Italy 2020).

While the pandemic has affected waste generation, it also caused a decrease of 8-9% in global plastic resin production during the first part 2020 (PlasticsEurope 2020). This decrease was due to the general economic downturn, as well as lower demand from industries such as vehicle makers, retailers, and machinery manufacturers (Recycling Product News 2020). At the same time, the economic downturn and reduction of international travel led to a fall in oil prices, which in turn lowered the cost of resin production. Consequently, by the end of 2020 the price of recycled plastic had risen well above that of virgin plastic (Hicks 2020).

Plastic waste and pandemics



The pandemic significantly challenged domestic waste recycling systems (World Economic Forum 2020). Temporary suspension of household waste collection in some jurisdictions in order to protect waste workers reduced the supply of recyclable material (Vanapalli 2020). In the United States 34% of recycling companies partially or completely closed (Prata et al. 2020). In many Asian countries, including India, Malaysia and Viet Nam, only around one-third of recyclers continued daily operations due to anti-pandemic measures (Maissan 2020). Many informal waste pickers have been seriously affected by stay-at-home orders and business closures. The poverty of informal workers in developing countries is expected to increase by 56% (Oxford Business Group 2020).

The highly infectious nature of COVID-19 has led to a large amount of PPE waste being classified as requiring special disposal. For example, in Wuhan, China at the height of the outbreak the amount of medical waste increased by 650% (from to 40 tonnes per day prior to the outbreak to 240 tonnes per day), far exceeding the capacity of the incineration system in place (49 tonnes per day) (Klemes et al. 2020; Tang 2020). The overload of incineration units has raised concerns about hazardous emissions such as those of dioxins and furans, especially from facilities that do not meet relevant national, regional and/or international standards or criteria to ensure protection of human health and the environment (Vanapalli 2020).

The quarantine restrictions implemented at many locations have had an impact on plastic waste volumes. Purchasing items, including food, online results in an increase in packaging waste. In Hong Kong, for example, people used 2.2 times more plastic take-away packaging on average than before the pandemic (Maissan 2020). In Thailand in the first half of 2020 the amount of plastic waste produced increased from 1,500 tonnes to 6,300 tonnes per day, largely because of a three-fold increase in food deliveries countrywide (Duer 2020; Maissan 2020). Since demand for plastics in other sectors such as construction and manufacturing has fallen, there may nevertheless have been an overall decrease in plastic waste generation (Klemes et al. 2020).

Pressure on the existing waste management infrastructure has also led to inappropriate waste management activities, including dumping and open burning (UNEP 2020). In 2020 in Dublin, Ireland, illegal dumping increased by 25% (Kelly 2020); in the United Kingdom illegal waste disposal rose by 300% (Duer 2020).

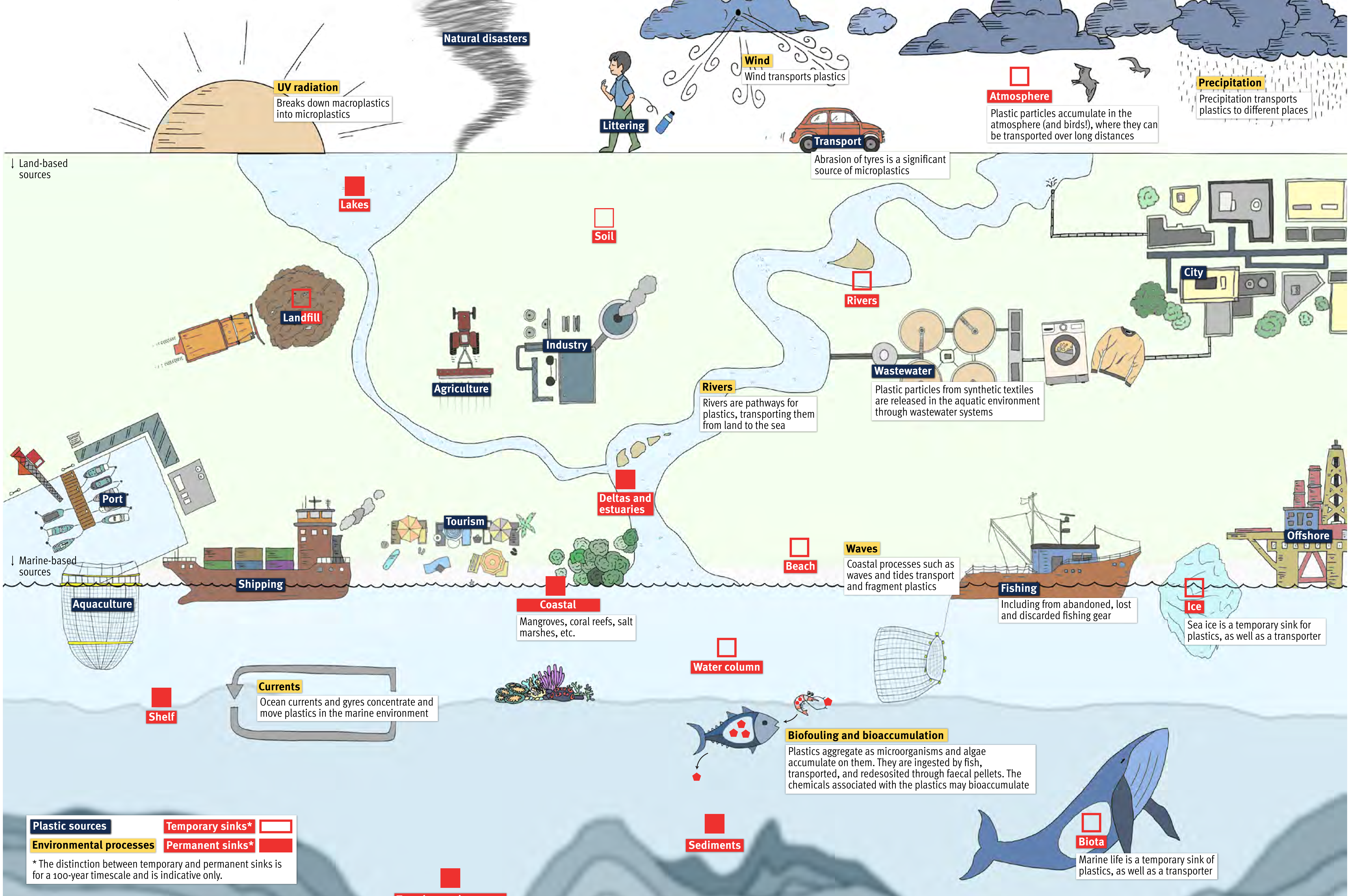
CHAPTER 12

Pathways and fate of plastic waste in the marine environment

Plastics enter the oceans via several pathways. Inputs are mainly from rivers, directly from land, sea-based, atmospheric, and to a smaller degree biological.

Annual plastic flows to the oceans are predicted to nearly triple between 2016 and 2040, from 11 million tonnes (range: 9-14 million tons) in 2016 to 29 million tonnes (range: 23-47 million tonnes), without meaningful action (The Pew Charitable Trusts and SYSTEMICS 2020). It has also been estimated that more than 1,000 rivers account for 80% of annual releases of plastic waste to the oceans from global riverine systems (ranging between 0.8 and 2.7 million tonnes per year), with small urban rivers among the most polluting (Meijer et al. 2021).

Sources, pathways and sinks of plastics



Source: GRID-Arendal (2021).

The input of plastics from sea-based activities (e.g. the fishing and shipping industries, recreation) is unknown, but it has been estimated to account for around 20% of all plastics reaching the ocean (Li et al. 2016). The fishing industry is a significant source of plastic pollution. In 2017, 5.7% of all fishing nets, 8.6% of all traps and 29% of all lines were lost to the world's oceans (Richardson et al. 2019). The annual input of plastics from this industry is estimated to be around 640,000 tonnes (Li et al. 2016). The direct input of plastics from both land-based and sea-based sources since the 1950s is estimated to be around 180 million tonnes (between 108 and 480 million tonnes) (Li et al. 2016).

The atmospheric transport of plastic particles is another way in which plastics are delivered to the oceans. Although the atmospheric contribution may be globally significant, it has not been quantified (Bergmann et al. 2017; Zhang et al. 2020). Seabirds and other animals consume plastic particles on land and excrete them into the ocean, but the amounts involved are probably small compared with other transport paths (Stewart et al. 2020).

The dispersal of plastic pollution in the marine environment depends upon the composition, shape and density of the plastic particles, as well as prevailing physical conditions. Particles composed of polymers with a higher density than that of seawater will sink to the seafloor. Recent research has found that microscopic particles are concentrated in coastal environments close to their sources (i.e. estuaries and deltas), with extreme values reported in fjords (up to 200,000 particles per kilogram of sediment; Harris 2020). A large share (66.8%) of all the buoyant plastic (>0.5 cm) released into the marine environment since the 1950s is stranded on the world's shorelines. In 2015 an estimated 46.7-126.4 million tonnes of microplastics were stored there (Lebreton et al. 2019). Over time some large plastic items will disintegrate under the influence of solar radiation and mechanical fragmentation by wave action and abrasion on beaches (Barnes et al. 2009), creating microplastics.

Polymers whose density is lower than or similar to that of seawater (i.e. polypropylene [PP], polyethylene [PE] and polystyrene [PS]) will float on the surface or remain suspended in the water column for years to decades. The estimated mass of the three most littered plastics (PP, PE and PS) combined of 32-651 µm size class suspended in the top 200 metres of the Atlantic Ocean is 11.6-21.1 million tonnes (Pabortsava and Lampitt 2020); extrapolating these figures to the global oceans yields an estimated 50-90 million tonnes. Processes such as biological fouling (Fazey and Ryan 2016), consumption by zooplankton and expulsion as faecal pellets (Cole et al. 2013), or flocculation and sinking as aggregates (Bergmann et al. 2017) remove plastics from the water column. However, whether the mass of plastics suspended in the water column is increasing – or decreasing and gradually removing plastic particles from the water column – is unknown.

In some environments where plastics are dispersed, they sink further offshore. Widespread distribution of litter, especially plastic items, was found on the seabeds of the North Sea, the English Channel, the Celtic Sea and the Irish Sea in abundances ranging up to 1,835 pieces/km^2 of seafloor (Maes et al. 2018). Over decade to century timespans, much of this plastic will be deposited in deep sea environments. Conservative estimates indicate that 14 million tonnes of microplastics are currently on the ocean floor at abyssal depths (Barrett et al. 2020). Plastics appear to occur in greater abundances in deep ocean trenches (Peng et al. 2018) and submarine canyons (Galgani et al. 2015; van den Beld et al. 2017; Zhang et al. 2020) than in sampled areas where these seafloor features do not exist.

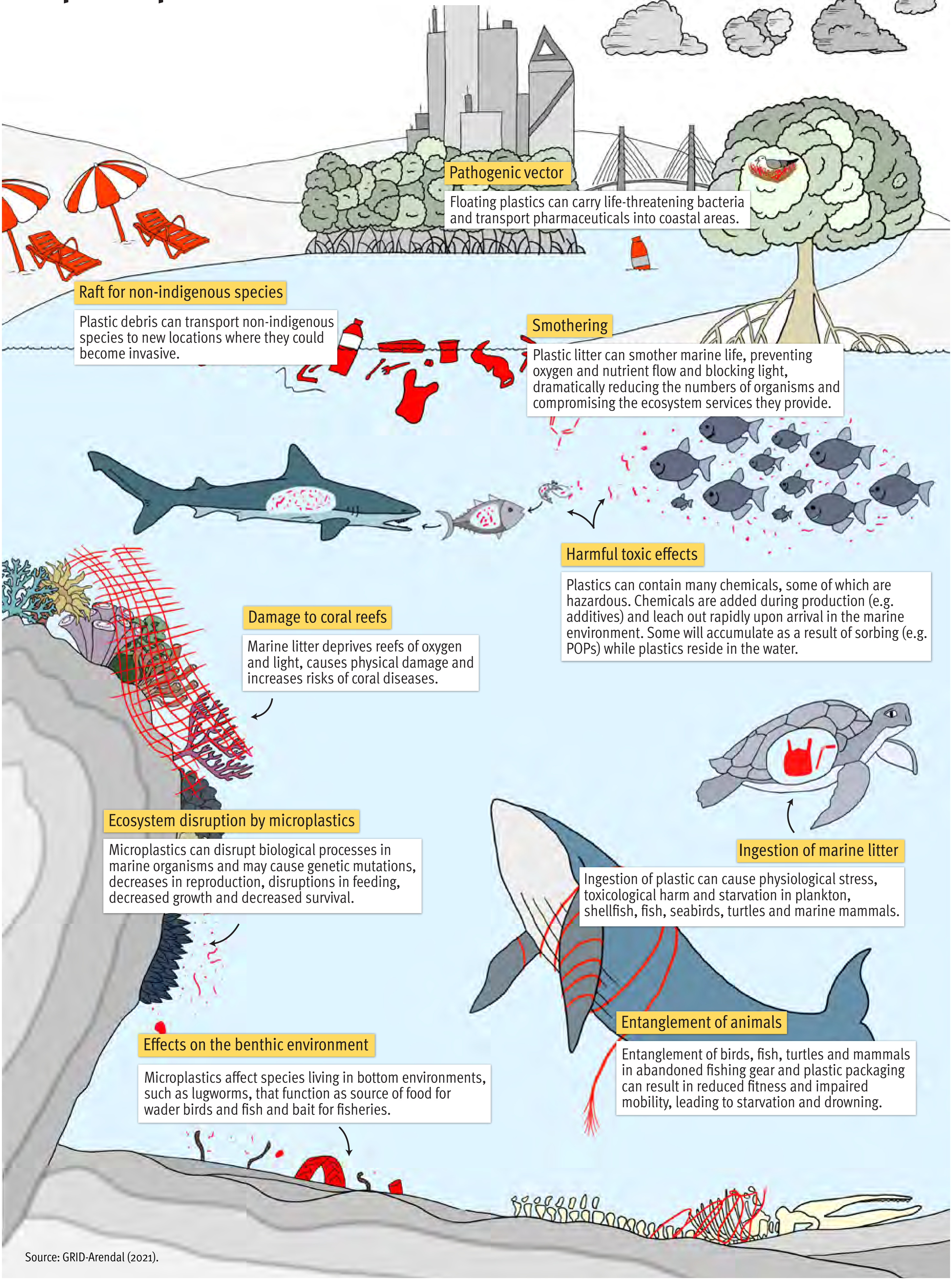
In the marine environment organisms at every level of the food web have been reported to ingest or interact with plastics (Maes et al. 2020a and b). This includes animals at the bottom of the food web, such as primary producers and consumers (algae/zooplankton), and higher-order organisms such as fish, turtles, seabirds, seals, whales and many more saltwater and freshwater species (GESAMP 2015; Thompson 2017).

CHAPTER 13

Impacts of plastic waste on the marine environment

The mismanagement of plastic waste has led to contamination of the entire marine environment, from shores to the deepest ocean sediments (e.g. Ryan et al. 2016; Woodall et al. 2014). Almost all marine species can be entangled in or ingest plastics, depending on their size, and ingestion can potentially expose them to hazardous additives contained in the plastic or to attached pathogens (Prinz and Korez 2020). Plastic waste can also be a host for a range of species, leading to rafting or species being transported long distances by floating plastics. This potentially increases species' geographical ranges and spreads invasive species and disease (Zettler et al. 2013; Keswani et al. 2016; Lamb et al. 2018; Rodrigues et al. 2019). Larger pieces of plastic can smother or cover habitats such as mangroves, mudflats and coral reefs (Uneputty and Evans 1997; Gregory 2009; Galgani et al. 2015). Plastic waste can also disrupt the movement of organisms (e.g. turtle hatchlings) (Ryan et al. 2016) and prevent the growth of seagrass meadows (Balestri et al. 2017).

Impacts of plastic waste on the marine environment



Source: GRID-Arendal (2021).

The presence of plastic in the marine environment has the potential to dramatically shift the ecology of marine systems (Villarrubia-Gomez et al. 2018). The existing volume of plastic and its continued leakage into the marine environment make removal impossible (Law and Thompson 2014). In addition to the lethal impacts of plastic, the sublethal impacts of microplastics can result in, for example, reduced primary production, growth, which can alter ecosystem functioning if severe enough (Prinz and Korez 2020). The extent to which ecological processes are impacted, including carbon flux to the deep ocean, remains unclear.

Microplastics are of particular concern because their size is within the optimal prey range for many animals (Wright et al. 2013). Field studies have demonstrated that they are ingested by a wide variety of marine animals living in the water column and on the sea floor (GESAMP 2015). They include organisms consumed by humans (e.g. fish and shellfish) and those (e.g. zooplankton) that play critical ecological roles. There is limited knowledge of how impacts on individual organisms could lead to consequences at the population level or to ecological harm (Galloway et al. 2017).

Microplastics often contain a complex cocktail of chemical additives (see Chapter 3), and they can absorb organic matter, bacteria and additional chemical contaminants from the surrounding seawater. Depending on their size, shape, surface area and toxicity, microplastics can have both physical and chemical effects on animals (Galloway et al. 2017).

Microplastics can adsorb and transport contaminants such as POPs from the surrounding environment, adding to the many chemical additives incorporated in plastics during their production. Marine organisms can ingest this plastic directly or by consuming other organisms that contain plastic.

Accumulation of microplastics by phytoplankton interferes with metabolism and photosynthesis and (in the case of both phytoplankton and zooplankton) directly impacts their growth, body weight and reproduction and increases mortality (Wang et al. 2019). These effects combined potentially threaten the very bottom of the marine food chain. There is also growing evidence of the bioaccumulation of microplastics at other levels in the food chain (Au et al. 2017).

Plastic particles can affect animals' tissues and cell receptors, presenting novel risks. Some plastic additives and persistent waterborne chemicals are endocrine disruptors, capable of activating hormone signal pathways and altering animals' metabolic and reproductive systems (Galloway et al. 2017). The effect of microplastics with regard to transfer of contaminants is context dependent and related to the establishment of balances between chemical loadings. The current consensus is that the net contribution of plastic ingestion to bioaccumulation of hydrophobic contaminants by marine animals is likely to be small in comparison with uptake of contaminants directly from water (Bakir et al. 2012; Koelmans et al. 2016).

The size and shape of microplastics (including microfibres) mean they have the potential to disrupt cellular and physiological processes in marine organisms (Sussarellu et al. 2016; Qiao et al. 2019; Zhao et al. 2021). Laboratory and field exposures to microplastics show they can adversely affect individual animals, reducing feeding and depleting energy stores, with knock-on effects on fecundity and growth, and even lead to death (Maes et al. 2020).

The generation of microplastic waste may be fuelling the spread of antimicrobial resistance, as plastic pollution facilitates increased gene exchange among bacteria (Arias-Andres et al. 2018; Imran, Das and Naik 2019).

CHAPTER 14

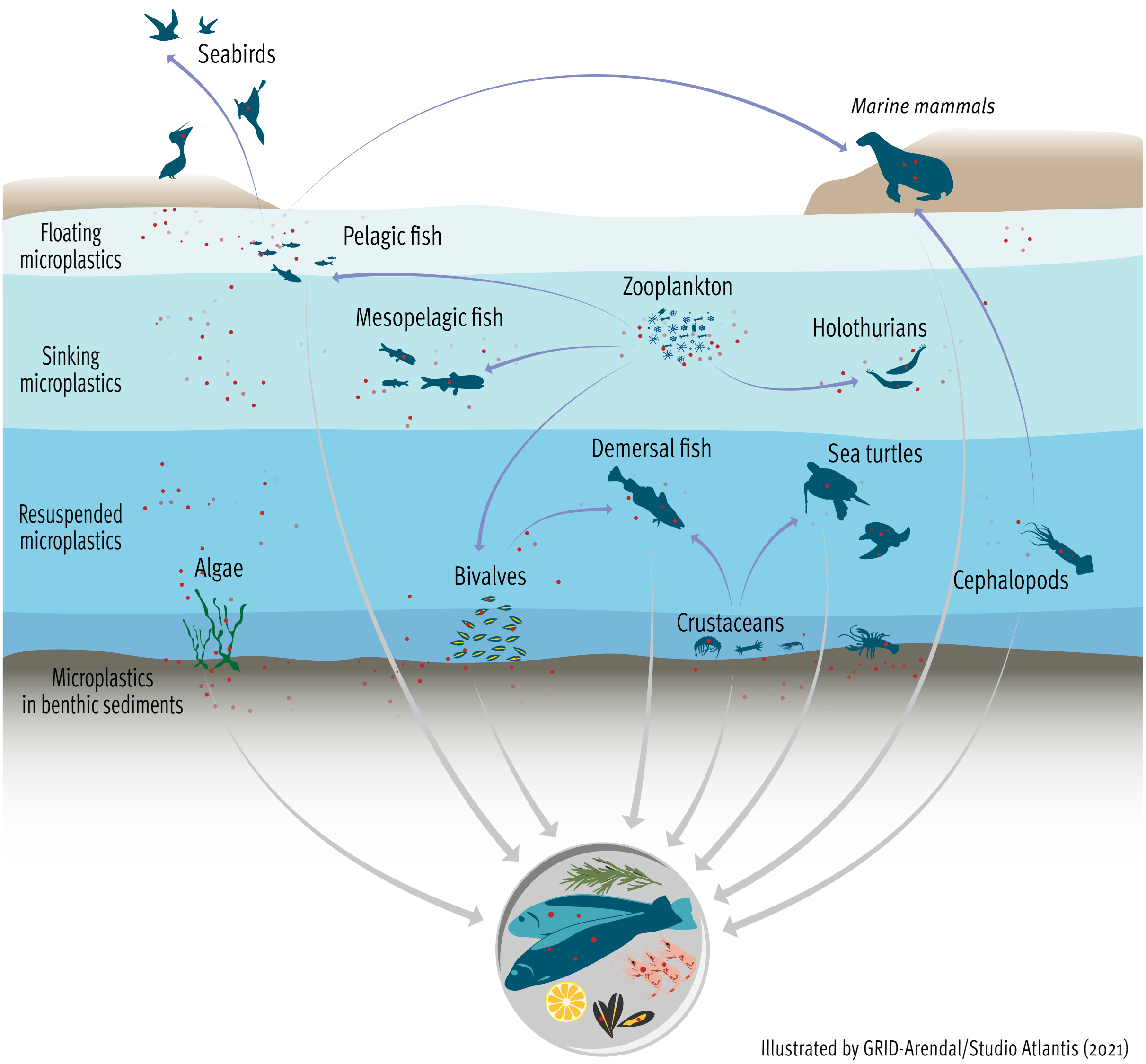
Human health impacts of marine plastic waste

Plastic particles make their way into the food we eat, the water we drink and the air we breathe. But are they damaging our health? The number of studies on the potential human health impacts of micro- and nanoplastics is growing. However, there is still major uncertainty about the level of our exposure (especially to nanoplastics) and the potential for these particles to cause harm (Lehner et al. 2019).

The mismanagement of waste has led to microplastic contamination of the whole marine environment, from the shore to the deepest ocean sediments (e.g. Ryan et al. 2009; Woodall et al. 2014). These microplastic particles can adsorb and transport contaminants from the surrounding environment, adding to the many chemical additives that are incorporated during the production of the plastic. Marine organisms can ingest this plastic directly, or by consuming other organisms that contain plastic.

Plastic particles can enter the human body through ingestion and inhalation, while nanoparticles may also be able to enter through the skin (Brouwer et al. 2016; Prata et al. 2020; Schneider et al. 2009 Vethaak and Legler 2021). Ingestion currently appears to be the major route of exposure to marine plastics. Plastic particles have been found in a wide range of marine organisms that are routinely part of the human diet, including mussels, oysters, prawns and fish (e.g. Besseling

Potential pathways of marine microplastics into our seafood



Illustrated by GRID-Arendal/Studio Atlantis (2021)

et al. 2015; Digka et al. 2018; Cho et al. 2019; Nelms et al. 2019). A recent review of microplastics in wild caught fish reported evidence of plastics in the intestinal tract of 65% of the 496 species examined (Markic et al. 2020). Studies suggest that eating whole organisms (e.g. mussels and oysters) as opposed to gutted animals provides the highest potential exposure to both physical and chemical toxicity (Smith et al. 2018).

People ingest an increasing amount of microplastics, and not only from marine organisms. Recent dietary studies suggest that adults in the United States could be consuming more than 50,000 pieces of plastic a year from all sources (Cox et al. 2019). What happens to this ingested plastic and any associated toxic chemicals is an growing area of research (Lehner et al. 2019). Some plastic additives (e.g. certain phthalates and their analogues) can act as endocrine disrupters which alter gene-environment interactions via physiological, cellular, molecular and epigenetic changes and affect the health of exposed humans, with evidence of transgenerational effects in animal studies (Gore et al. 2015).

A large number of systematic reviews have revealed associations between environmental exposure to existing or banned plastic additives and health outcomes, including reduced reproduction (Dorman et al. 2018; Hu et al. 2018), cardiovascular disease (Golestanzadeh et al. 2019; Hu et al. 2019), Type 2 diabetes (Hwang et al. 2018; Shoshtari-Yeganeh et al. 2019), childhood obesity (Kim et al. 2019), asthma (Jeddi et al. 2016) and altered neurodevelopment (Lee et al. 2018; Rochester et al. 2018). Although associations are apparent, findings are somewhat inconsistent and it is difficult to attribute causes (Lakind et al. 2014). Further high-quality longitudinal cohort studies will be required to establish causal links between exposure and health outcomes, as well as to determine whether exposure to multiple additives in plastics compounds their impacts.

In addition to any risks from hazardous chemicals, the presence of microplastics and nanoplastics may pose risks to human health. It appears that at least some of the particles we swallow pass through the digestive tract and are excreted (Liebmann et al. 2018). However, ingested particles less than 2.5 μm in size can move through the epithelial layer of the gastrointestinal tract and into the circulatory system (Campanale et al. 2020). A study in which microplastics were added to post mortem samples of liver, spleen, kidney and lung demonstrated the feasibility of detecting microplastics in human tissue (Kelkar et al. 2020), paving the way for future studies to determine whether microplastics are accumulating in the body.

Toxicological studies using a range of organisms (including mammals), as well as cell cultures, have shown that micro- and nanoplastics can initiate adverse cellular events (oxidative stress and inflammation responses). However, there is currently insufficient information to connect plastic particle toxicity with adverse human health outcomes (Hu and Palić 2020; Vethaak and Legler 2021).

CHAPTER 15

The economic costs of marine litter and plastic pollution

The economic costs of marine litter and plastic pollution can be divided into costs incurred during preventive activities, costs of direct damage to equipment and commercial stocks, costs of remedial activities, and indirect costs of inaction (UNEP 2018). Investing in the prevention of waste and pollution at their sources is less expensive than remediation (UNEP 2018).

Prevention costs involve a range of actions by consumers, civil society organizations, governments and industry to reduce the amount of waste and litter entering the oceans, thereby avoiding damage and remediation costs in the future. These actions include reducing and improving consumption and production practices, as well as improving waste management. For example, Canada has estimated that its countrywide Strategy on Zero Plastic Waste could help save Canadian dollars (CA$) 500 million in annual costs while creating 42,000 direct and indirect jobs and preventing the emission of 1.82 million tonnes of CO_2 equivalent (Canada 2019). By increasing plastic waste recycling rates from the current 10% to 100%, an estimated CA$ 7.8 billion loss to the Canadian economy could be avoided (Canada 2019). Municipalities along the Adriatic and Ionian Seas spend approximately 5% of their annual budgets on clean-up of marine litter (Vlachogianni 2017).

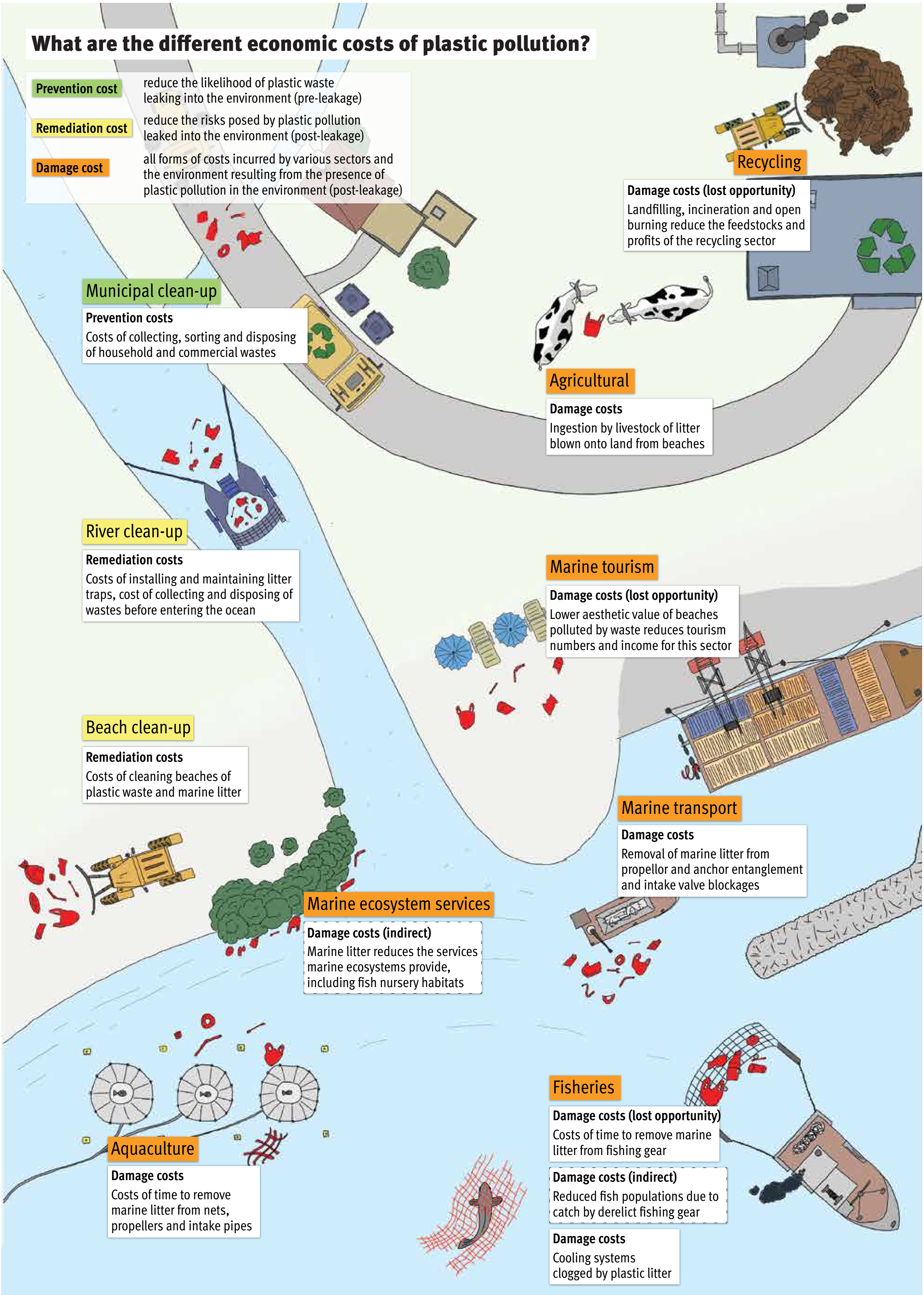
Damage costs can be incurred by those who use the oceans for leisure or by marine industries, particularly marine tourism. These costs result from the loss of ecosystem services provided by healthy oceans. The economic impacts on those who enjoy the oceans for leisure activities, as well as on marine and coastal ecosystems, are more challenging to calculate and are mostly unknown.

The total cost of damage to marine industries in 2015 in the Asia-Pacific Economic Cooperation (APEC) region has been estimated at US$ 10.8 billion annually, a substantial increase over the 2009 estimate of US$ 1.26 billion (McIlgorm et al. 2020). The APEC region's share of global gross domestic production (GDP) is 60% (APEC 2018). In 2015 the direct cost impacts of marine litter on marine tourism have been estimated at US$ 6.41 billion (59.2% of total damage costs), while those on fisheries and aquaculture have been estimated at US$ 1.47 billion (13.4%) and those on transport and shipbuilding at US$ 2.95 billion (27.0%) (McIlgorm et al. 2020). Similar marine economic sectors have been studied in the Adriatic and Ionian Seas, with annual per vessel costs of marine litter reaching US$ 6,464 (a total loss to the fisheries sector of US$ 21.86 million per year) and costs for aquaculture installations of US$ 3,880. Businesses in the tourism sector lost an average of US$ 6,833 per year and harbours spent an average of US$ 10,238 per year managing marine litter (Vlachogianni 2016). More broadly, economic losses in 2018 of US$ 6-19 billion were estimated in 87 coastal countries in Europe, Asia, Africa, the Middle East, the Americas and Oceania (Deloitte 2019).

Agricultural operations near coastlines where marine litter accumulates can experience harm to livestock through ingestion and damage to machinery because of clogging (KIMO 2010). Litter has also blocked drains and waterways with severe consequences, leading Bangladesh, for example, to ban plastic bags in an attempt to keep them from accumulating in waterways and on land (Ritch et al. 2009).

Damage costs may also result from lost opportunities for industries due to marine litter. Perceptions of reduced aesthetic value leads tourists to favour alternative, less polluted locations, reducing incomes for businesses operating at less visited beaches. Those avoiding polluted areas can also incur additional costs. Marine litter on beaches in Orange County, California (United States) was reduced by 25%, saving visitors to those beaches approximately US$ 32 million in unnecessary costs over three months since they did not have to travel further to less polluted beaches (NOAA 2014).

Remediation costs are incurred through activities such as clean-up of litter from rivers and beaches; street sweeping; installation, cleaning and maintenance of stormwater capture devices; and public education (NRDC 2013). The estimated cost of removing all marine plastic litter from a remote atoll in the Seychelles was US$ 4.68 million with 18,000 hours of labour (Burt et al. 2020). In Germany removal of cigarette butts and single-use plastic cups cost over US$ 414 million


What are the different economic costs of plastic pollution?
Prevention cost
reduce the likelihood of plastic waste leaking into the environment (pre-leakage)
Remediation cost
reduce the risks posed by plastic pollution leaked into the environment (post-leakage)
Damage cost
all forms of costs incurred by various sectors and the environment resulting from the presence of plastic pollution in the environment (post-leakage)
Recycling
Damage costs (lost opportunity)
Landfilling, incineration and open burning reduce the feedstocks and profits of the recycling sector
Municipal clean-up
Prevention costs
Costs of collecting, sorting and disposing of household and commercial wastes
Agricultural
Damage costs
Ingestion by livestock of litter blown onto land from beaches
River clean-up
Remediation costs
Costs of installing and maintaining litter traps, cost of collecting and disposing of wastes before entering the ocean
Marine tourism
Damage costs (lost opportunity)
Lower aesthetic value of beaches polluted by waste reduces tourism numbers and income for this sector
Beach clean-up
Remediation costs
Costs of cleaning beaches of plastic waste and marine litter
Marine transport
Damage costs
Removal of marine litter from propellor and anchor entanglement and intake valve blockages
Marine ecosystem services
Damage costs (indirect)
Marine litter reduces the services marine ecosystems provide, including fish nursery habitats
Fisheries
Damage costs (lost opportunity)
Costs of time to remove marine litter from fishing gear
Damage costs (indirect)
Reduced fish populations due to catch by derelict fishing gear
Damage costs
Cooling systems clogged by plastic litter
Aquaculture
Damage costs
Costs of time to remove marine litter from nets, propellers and intake pipes

(DW 2020). In the Republic of Korea US$ 282 million was spent over five years to remove marine litter (KOEM 2018; MOF 2018), while Japan spent US$ 450 million over eight years to do so (MOE 2018).

Japan has committed funds to encourage fishers to take action with regard to the collection, return and treatment of marine litter found at sea (MOEJ 2019), with similar costs incurred in other countries where such projects are underway. In several cases liability costs to insurers for remediation of pollution by pre-production plastic pellets resulting from lost and damaged shipping containers have been in the hundreds of millions of dollars (McIlgorm et al. 2020). Port authorities are using cleaning barges, for example in the Republic of Korea (MOF 2018a and b), with that country incurring a cost of US$ 157.5 million over five years (MD 2017 and 2018).

The costs of inaction have been estimated for the APEC region, where continued estimated damage to marine economies of US$ 10.8 billion per year, projected to 2050, would have a present value of US$ 216 billion (McIlgorm et al. 2020). This projection is likely to be conservative, as it does not account for a projected tripling of global plastic production by 2050. Recognizing the costs of inaction, Indonesia has committed to reduce all waste by 30% by 2025 while properly handling 70% of marine litter by 2025 compared with 2017 levels, using a cross-government collaborative approach involving 16 government agencies (Ministry of Environment and Forestry 2020).

Damage to ecosystem services is challenging to calculate. It has been proposed that a 1% decline in annual marine ecosystem services could equate to an annual loss of US$ 500 billion in global ecosystem benefits (Beaumont et al. 2019). The environmental costs of plastic consumer products and packaging alone has been estimated at US$ 139 billion (Trucost 2016). Direct impacts of marine litter on fish catch volumes and the sanitary quality of fish also impact the livelihoods of those fishing from polluted areas. Microorganisms and pathogens can colonize the surface of marine litter (Caruso 2015), with possible human health impacts.

Communities may suffer social impacts differently, with the impacts of exposure and management of plastic pollution often falling on poorer urban and rural women (UNEP-COBSEA-SEI 2019). Litter also increases the risk of water-borne diseases (Ritch et al. 2009).

More research is needed to better understand the direct and indirect costs of losses to ecosystem services resulting from marine litter and plastic pollution, together with socio-economic costs to communities that depend on these services for their livelihoods.

CHAPTER 16

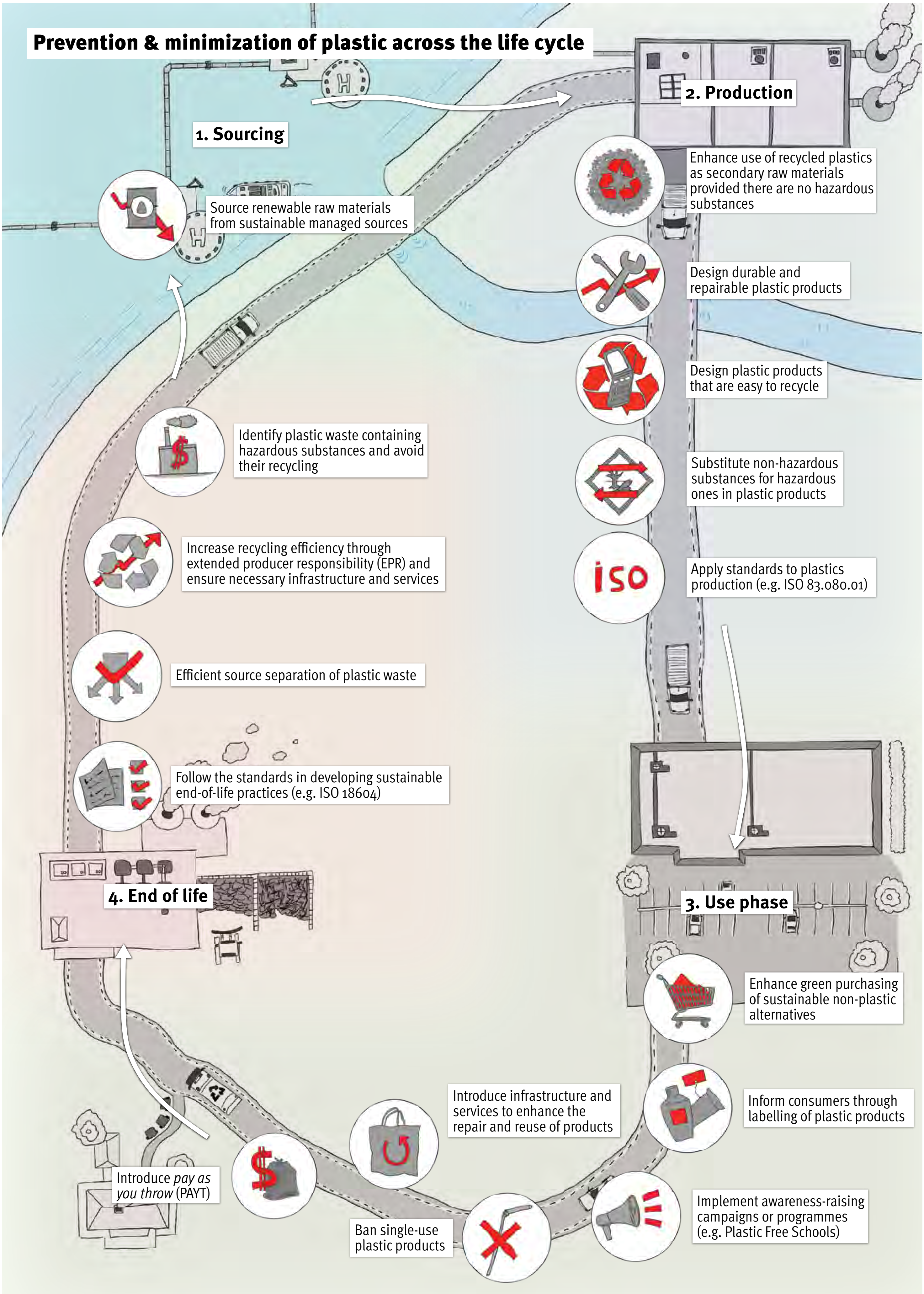
Prevention, minimization and reuse

The waste hierarchy prioritizes waste prevention and minimization, followed by reuse, recycling, other recovery (including energy recovery) and final disposal. It is intended to optimize the use of resources and eliminate the need for final disposal as much as possible. Plastic waste is not just an environmental issue, but also a resource issue: resources are not infinite.

There will not be one quick solution to all the problems related to plastic waste, but rather a combination of different solutions targeting all levels of society and adapted to the specific needs and capacity of each person or country. Eliminating single-use plastic items, reducing the unnecessary and problematic use of plastics, and preventing leakage are a good start. Plastic recycling in its current form, although essential, is not an adequate solution to the plastic waste crisis. Better systems, materials and products need to be designed with circularity in mind. Our goal should be to achieve zero plastic pollution by taking actions to produce and consume less plastic, recycle more of it, and support innovations to improve plastic waste reduction systems.

Product design and manufacturing influence a product's life cycle. Designers need to ensure that products have a long and/or circular life. If a product is expected to be in use for a long time, its design should give preference to durability and reparability. Short-lived products need to be designed so they can be easily recycled into high-quality secondary plastic (ECOS 2019). The redesign of plastic packaging is fundamental. Otherwise, about 30% of plastic packaging waste will never be reused or recovered (Ellen McArthur Foundation 2017).

Improving production and design and eliminating some non-functional plastics will not be sufficient. Changing consumer behaviour is also extremely important. What people buy – and how they use and dispose of products – have a significant impact on production processes and levels of plastic leakage (UNEP 2020; UNEP 2021). Increasing consumer awareness of environmental end-of-life solutions for products (recyclability, compostability, biodegradability), the benefits of waste separation and recycling practices, and the environmental impacts of littering can influence purchase choices (UNEP 2019). However, facilities are needed where "greener" products can be processed, such as recycling infrastructure and industrial composting facilities. Incentives are also needed to encourage choosing renewable alternatives, as well as reuse and repair solutions.


Prevention & minimization of plastic across the life cycle
1. Sourcing
Source renewable raw materials from sustainable managed sources
2. Production
Enhance use of recycled plastics as secondary raw materials provided there are no hazardous substances
Design durable and repairable plastic products
Design plastic products that are easy to recycle
Substitute non-hazardous substances for hazardous ones in plastic products
ISO
Apply standards to plastics production (e.g. ISO 83.080.01)
3. Use phase
Enhance green purchasing of sustainable non-plastic alternatives
Inform consumers through labelling of plastic products
Implement awareness-raising campaigns or programmes (e.g. Plastic Free Schools)
Ban single-use plastic products
Introduce infrastructure and services to enhance the repair and reuse of products
Introduce *pay as you throw* (PAYT)
4. End of life
Follow the standards in developing sustainable end-of-life practices (e.g. ISO 18604)
Efficient source separation of plastic waste
Increase recycling efficiency through extended producer responsibility (EPR) and ensure necessary infrastructure and services
Identify plastic waste containing hazardous substances and avoid their recycling

Labelling is one way to provide product information. While the criteria for eco-labelling continue to evolve, advertising a product as sustainable can benefit sales. Environmental claims on ecolabels can also make consumers aware of plastic pollution and trigger behavioural change towards prevention, minimization and reuse. Current labelling systems can be confusing and inconsistent. For example, the difference between "made from recycled plastic" and "recyclable" is not always clear to consumers (UNEP 2020). Similar problems exist with terms such as "bioplastics" and "biodegradable", or "compostable", "home compostable" and "industrial composting". Environmental claims can also be misleading – a practice referred to as "greenwashing". Manufacturers may use designations such as "eco-friendly", "sustainable" or "ethical" which are not credible or verified. Information about plastic additives is often not given on products, so that consumers may not be aware that these products contain potentially hazardous substances. Understanding what is in plastics could lead to more sustainable consumption and recycling, which would in turn encourage better design.

Awareness-raising campaigns have an important role to play in developing responsible consumer and waste management behaviour (UNEP 2018). Messages explicitly targeting identified product user groups such as women, men and youth have been shown to be effective (Woroniuk and Schalkwyk 1998). In Bali, for example, the "Bye Bye Plastic Bags" initiative, a campaign led by youth designed to mobilize people to say no to plastics, influenced the local government to phase out single-use plastic bags (UNEP 2018). Other innovative approaches which have influenced governments and industry include a mobile phone application developed by two Dutch non-governmental organizations (NGOs), the Plastic Soup Foundation and the North Sea Foundation. This application helps consumers identify products known to contain microbeads (Chang 2015).

Plastics prevention and minimization strategies also include regulatory instruments such as standards for plastic design, production and recycled content, as well as plastic product bans or fees. More than 140 countries, including more than 30 in Africa, have instituted partial or full bans on single-use plastic bags (Lerner 2019; UNEP 2020). Nevertheless, some governments do not have the resources to enforce such bans. Socially or economically disadvantaged people may also suffer if alternatives are more expensive, while bans can exacerbate other environmental problems.

As part of its first circular action plan, in 2018 the EU launched a European strategy for plastics aimed at reducing the top 10 marine polluting items, which include plastic bags and straws (European Environment Agency 2019). Other countries are introducing measures to phase out single-use plastic products. For example, in 2010 Japan prohibited the distribution of drinking water in small single-use bottles. Local governments installed drinking fountains and bottle filling stations to assist in reducing the number of PET bottles (FoE Japan and IGES 2014).

There are also a growing number of Plastics Pacts – local and regional initiatives that work towards bringing about a plastic circular economy. As of June 2021, there were 11 of these pacts (nine country-based and two regional) in the Plastics Pact Network (Ellen MacArthur Foundation 2020). In addition, over 500 organizations including industry (representing over 20% of all plastic packaging produced globally), together with governments from all regions, have committed to specific actions and targets across the plastics life cycle in the New Plastics Economy Global Commitment led by the Ellen MacArthur Foundation in collaboration with UNEP (Ellen MacArthur Foundation 2017).

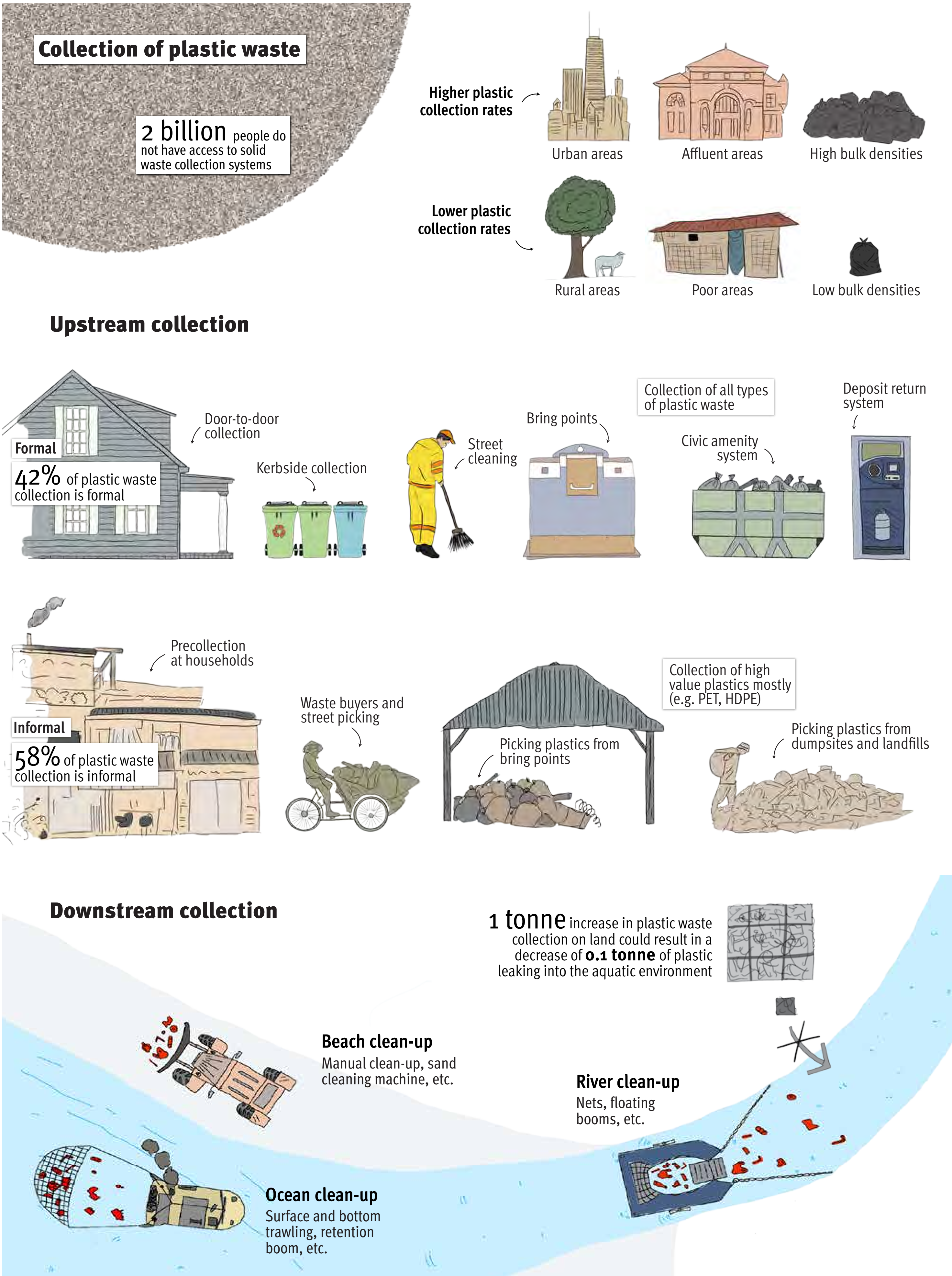
CHAPTER 17

Collection of plastic waste

A large portion of the world population (at least 2 billion people) may lack access to solid waste collection systems (UNEP and ISWA 2015), which increases the risk of plastic waste escaping into the environment. Collection rates differ across countries: the average collection rate is 36-43% in low income countries, 64-68% in lower-middle income countries, 82-85% in upper-middle income countries, and approaching 100% in high income countries (UNEP and ISWA 2015).

Municipal waste collection is an essential first step in the proper management of plastic waste. It determines what kind of systems can be put in place for downstream pre-treatment, sorting, recycling, recovery and final disposal. Three-quarters of plastic items from land-based sources that end up in oceans come from uncollected waste or litter (Ocean Conservancy 2015). Proper collection services can lead to increased plastic waste collection from residential areas and less dumping and open burning of plastic waste.

Plastic waste for recycling can be separated by householders at source or sorted at a facility. This waste can be collected in a number of ways (e.g. kerbside, door-to-door, at specialized drop-off points or using deposit/return systems). In Europe door-to-door separate collection systems are reported to have attained the highest annual rates of plastic collection per capita (9 kg/capita), followed by drop-off points, (7 kg/capita) door-to-door co-mingled collection, (7 kg/capita), and civic amenity public recycling bins (1 kg/capita) (European Commission 2015).



Sources: Slat (2014), ISWA (2015), Ocean Conservancy (2015), UNEP (2015), Lau et al. (2020). Illustration by GRID-Arendal (2021).

Established collection schemes vary greatly, not only among countries but also among municipalities and regions. This can make it challenging to operate a regional or national recycling system, as inputs from different municipalities are inconsistent. Harmonizing collection systems is a demanding yet important task for legislators. With increased and streamlined collection, reliable flows of plastic waste to recycling facilities can be achieved.

Providing adequate waste collection services, especially in municipalities in developing countries and countries with economies in transition, is limited by city budgets. According to the World Bank (Kaza et al. 2018), adequate waste management services in developing countries account for 20-50% of municipal budgets. Waste collection and transportation make the greatest demands on municipal budgets (UN-HABITAT 2010). Costs could potentially be reduced by contracting private companies or involving volunteers in waste collection (UNEP and ISWA 2015). The lack of strategic plans and inadequate financial frameworks for waste collection are also major barriers to achieving an effective waste management system (Kumar et al. 2017).

Informal waste workers play a crucial role in the collection of plastics, especially in countries where robust waste management services are lacking. Because these workers use equipment such as wheelbarrows and carts, they can reach places that may be inaccessible to the larger vehicles used in the formal sector (Basel Convention 2019). However, informal waste workers are less likely to collect low-value, high-bulk plastic waste (e.g. low-density polyethylene [LDPE] films). They concentrate on high-value plastic waste such as polyethylene terephthalate (PET) and high-density polyethylene (HDPE), which limits collection to only 20% of the municipal plastic waste stream (Ocean Conservancy 2015). According to the Ocean Conservancy (2015), the collection of 1 kg of plastic bags requires 61 minutes and the economic value of the plastic is US$ 0.05, while collection of 1 kg of PET requires 37 minutes and the plastic is worth to US$ 0.23. To improve services and conditions, municipalities need to integrate informal waste workers into formal waste management programmes. By assigning rights over recyclables, they could guarantee both livelihoods and services (Basel Convention 2020).

Better collection upstream would reduce the amount of plastic escaping into aquatic environments in the future. An estimated 19 to 23 million tonnes (11%) of plastic waste generated globally in 2016 entered aquatic ecosystems (Borelle et al. 2020). Plastics reach the oceans along a variety of pathways, but rivers are a primary source. Removing plastics from rivers (e.g. with nets and floating booms) before they find their way to the oceans can be an effective way to reduce plastic pollution.

Manual removal of marine litter, mainly carried out by volunteers during beach or coastal clean-ups, is a well-known collection method. Other methods involve surface or bottom trawling, the use of retention booms that trap floating litter on the sea surface, and diving to remove litter from the seafloor (Schneider et al. 2018). The efficiency of these methods in terms of cost, and the amounts and types of litter collected, have not been well documented. Often collected marine litter is heterogeneous and contaminated, which means intensive effort is required to sort and clean it (Iñiguez et al. 2016).

Even if the collection of marine litter increases in the future, it will not necessarily reduce the volume of plastics in the oceans. To drastically cut the amount of marine litter, we need a significant reduction in or simply a halt to inputs of litter to the marine environment. A first important step would be to reduce plastic consumption. Secondly, there is a need to create sustainable circular markets and expand waste collection services to more households, particularly in developing countries and countries with economies in transition, while ensuring that women (who are mostly central to household waste management) are included as key stakeholders. According to Lau et al. (2020), an increase in plastic waste collection of 1 tonne, through actions in both the formal and informal sectors, could result in an average 0.10 tonne decrease in aquatic plastic pollution.

CHAPTER 18

Recycling, other types of recovery operations, and final disposal

In recycling, other types of recovery operations and final disposal the waste hierarchy (see Chapter 16) should be kept in mind. End-of-life options for plastics vary depending on the types of materials involved and how easy it is to separate these materials after the plastics enter the waste stream. Disposing of plastic waste in landfills or by means of open burning or incineration without energy recovery leads to loss of resources. Recycling, on the other hand, enhances the recovery of resources and is seen as part of the solution to reduce marine litter. Geyer (2020) estimated that in 2017 around 21% of non-fibre plastics globally were recycled, while 26% were incinerated.

Recycling, recovery, and final disposal of plastic waste

	Mechanical recycling	Chemical recovery	Incineration	Landfilling
global % of plastic waste treatment *(2016 figure)*	16%	<1%	25%	40%
Application	All countries, but more sophisticated mechanical recycling equipment present in advanced economies.	Advanced economies only, due to high capital costs and specific expertise required.	Commonly found in both developed and developing countries.	Commonly found in both developed and developing countries.
Potential environmental impacts	Air emissions in the form of dust Wastewater release from washing of plastic Air emissions associated with heat production Electricity consumption	Ash containing heavy metals	Air emissions of CO_2, CO, oxides of nitrogen Toxic gases: acetaldehyde, acetone, benzaldehyde, benzole, formaldehyde, phosgene, dioxins, etc. Ash that contains heavy metals	Escape of light weight plastics in environment due to wind or rain Contamination of soils and groundwater of toxic substances/additives
Challenges / Drawbacks	Applied to thermoplastics (PET, HDPE, and PP) Requires efficient collection system Feasible for homogenous single polymer streams or mixtures that can effectively be seperated Downcycling (deterioration of products) Affected by low oil prices	Chemical recycling technologies are sophisticated and require specific expertise High capital costs and requires large volumes of polymers to be economically viable New technologies that are often at pilot stage and not yet fully commercialized	Incineration of plastics without energy recovery leads to a loss of resources	Loss of resources as none of the material is recovered Impacts on the environment and human health
Advantages / Opportunities	Less energy demanding Commercially available, mature and well-known technology	New opportunity to recycle more plastics and put less pressure on collection systems Can apply to wider range of plastic waste that is currently difficult to recycle	Can be used for non-recyclable or hard to recycle plastic waste Plastics high calorific values generate considerable energy Energy can be used to produce heat and/or electricity for industrial use	Well-managed landfills result in limited immediate environmental harm and partly avoid escapes in the environment
Looking forward	Design of products for recycling Advanced sorting technologies Enhance source separation of plastic waste Enhance market of secondary plastics	Additional funding to upscale technology and broaden its usage to more plastic types, and geographic regions	Incineration taxes or bans could enhance recovery of plastics for recycling	Landfill taxes or bans could enhance recovery of plastics for recycling

Sources: Hopewell et al. (2009, EASEWASTE (2013), Nagy et al. (2016), McKinsey & Company (2018) Vanapelli et al. (2018), Kumer et al. (2019), Amos (2020). Illustration by GRID-Arendal (2021)

Plastics can be recycled mechanically or chemically. The choice of method is determined by the type of plastic polymers, the availability and maturity of technologies, and their viability in different socio-economic environments. Each method has its advantages and disadvantages (Singh et al. 2016). Mechanical recycling is the simplest process. It involves sorting, cleaning, granulation/shredding, drying, melting, extrusion and pelletizing (Ragaert et al. 2017). Mechanical recycling rates vary. They are influenced by the local economy and the strategies used to enhance recycling. Economies in transition tend to have higher recycling rates. For example, plastic recycling rates in Brazil, China and India are between 20% and 60% (Basel Convention 2020). In Australia, the Balkans region and the United States, for example, where incentives to enhance recovery and recycling are limited, plastic recycling is low (10-15%), while in Western Europe and Japan, where recycling is encouraged through strategies and regulations, plastic recycling rates for plastic are around 25-30% (Basel Convention 2020).

Cost-effective and efficient recycling of the mixed plastic stream, along with high contamination levels, are perhaps the biggest challenges facing the (mechanical) recycling industry (Vilaplana et al. 2007). According to a recent Greenpeace (2020) report, mixed plastics in the United States account for around 69% of all plastics. Technically it is possible to separate most mixed plastics into recognizable streams, but not all polymers can be mechanically processed (depending on chemical makeup, mechanical behaviour and thermal properties). Only thermoplastic polymers such as polyethylene (PE), polypropylene (PP) and polyethylene terephthalate (PET) are mechanically recycled (Ragaert 2016; Garcia and Robertson 2017). In addition, the recycling industry is most interested in higher-value plastics such as PET bottles and high-density polyethylene (HDPE) containers (Garcia and Robertson 2017). In the United States in 2015, 18% of PET was recycled, but only 10% of HDPE, 6% of low-density polyethylene/linear low-density polyethylene (LDPE/LLDPE), and less than 1% of PP and polystyrene (PS) (US EPA 2018) were recycled.

Mechanical recycling is being made increasingly effective by technological advances, such as systems for the collection, sorting and reprocessing of recyclable plastics. Innovations include increasingly reliable technology to detect different types of plastics and sophisticated decision-and-recognition software that improves automated sorting, differentiating between plastic types and colours.

The effectiveness of mechanical recycling of plastics could be dramatically increased through the redesign of plastic products. For example, it would be easier to recycle items made from one type of polymer instead of multiple types. Strong secondary markets for recycled materials are also key to increasing plastic recycling rates.

An alternative to mechanical recycling is chemical recycling, which produces plastic feedstocks that can replace virgin plastic feedstock (Thiounn and Smith 2020). Research is focused on improving chemical recycling methods to accommodate mixed plastic waste, including traditionally non-recyclable polymers, thus avoiding the need for sorting (Solis and Silveira, 2020). Methods that allow repeated chemical recycling of polymers are also being explored (Zhu et al. 2018). Although chemical recycling is rapidly developing, however, it is not yet very widespread.

If mechanical and chemical recycling are not available, energy recovery is seen as the next most environmentally favourable way to deal with non-recyclable or hard to recycle plastic waste. Energy recovery from plastics occurs at waste incineration plants, cement kilns and, in rare cases, co-combustion of waste plastics in power plants. These types of energy recovery units are very costly and need to be equipped with modern cleaning systems that filter air emissions and manage bottom ash and fly ash in an environmentally sound manner. Moreover, energy recovery does not exclude the need for waste minimization and could disincentivise reduction, reuse and recycling.

Landfilling in engineered landfill sites may be seen as a less desirable end-of-life option for plastics. If not carried out in an environmentally sound manner, it could pose a number of environmental risks including the risk of lightweight plastics escaping into the environment due to wind or strong rainfall and the high probability that hazardous substances will migrate into aquifers. Storing waste in landfills under inadequate conditions is still a very common disposal method in many countries. In addition, a large share of plastic waste is mismanaged in dumpsites (which can collapse), burned in the open, abandoned at recycling and disposal facilities, or released into terrestrial or aquatic environments. Such practices transfer the pollution burden to the air, water and soils, contaminating ecosystems with macro- and microplastics and emitting greenhouse gases and hazardous pollutants.

Even with changes to production and consumption, some waste will always be produced. Dealing efficiently with this waste requires concerted global action to harmonize standards that promote preparation for reuse and material-efficient recycling. Standards applied to plastic products are important to ensure quality (e.g. ISO 83.080.01 on plastics) as well as sustainable end-of-life practices (e.g. ISO 18604 on material recycling). However, standards often fail to address real-life conditions such as the status of local waste management systems and the availability of necessary services and/or infrastructure (Basel Convention 2020).

Pros and cons of biodegradable plastics and bioplastics

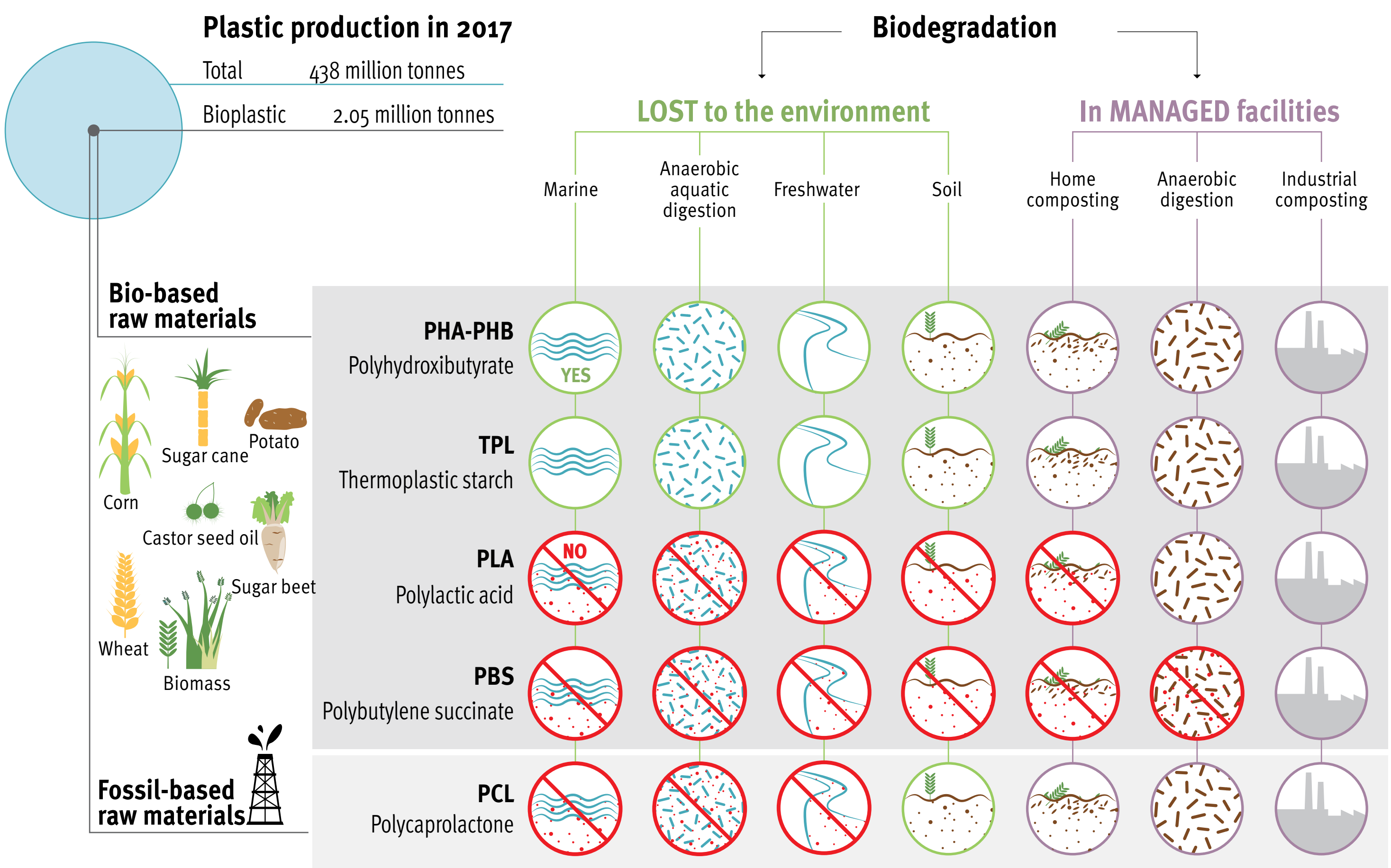
Biodegradable plastics and bioplastics are often marketed as the solution to plastic pollution. While they may potentially provide significant benefits, they currently present a number of challenges and in some cases may even worsen the overall plastic pollution problem.

Bio-based plastics were first introduced in the late 1980s by several plastic companies in the United States (Brebbia et al. 2014). Since then they have gained popularity on the market as an alternative to fossil-based plastics (Pathak et al. 2014; Ruggero et al. 2019). Driven by growing awareness of the hazards of conventional plastics, the global market for bioplastics experienced rapid growth in the last decade. Production increased from 0.7 million tonnes in 2010 to 2.11 million tonnes in 2019, with more than 45% of production in Asia (European Bioplastics 2019). However, bioplastics production still makes up only a small fraction of plastics manufactured (in 2018 it accounted for only 0.6% of total plastics production) although increased demand is expected to continue to accelerate growth. Brazil and India are the largest producers of sugarcane (International Sugar Organization 2019) and Brazil, China and the United States are the largest producers of maize (corn) (Statista 2019).

Most popular biodegradable bio-based plastics on the market are the polylactic acid (PLA), polyhydroxyalkanoate (PHA) and the starch-based polymer polybutylene succinate (PBS) (Greene and Tonjes 2014). They are usually substituted for conventional plastics such as polypropylene (PP), polyethylene terephthalate (PET) and polystyrene (PS). Renewable biological resources, often referred as bio-based content for the production of these plastics, are sourced from crops such as sugarcane, soy, maize and potatoes.

Bioplastics are used in sectors such as packaging, textiles, automotive applications and agriculture

Bioplastics - not always bio-based, not always biodegradable...



Sources: European Bioplastics (2018), Narancic et al. (2018) European Bioplastics (2019), Geyer (2020). Illustrated by GRID-Arendal/Studio Atlantis (2021).

(European Bioplastics 2018). Flexible and rigid packaging is the main application, utilizing 0.69 million tonnes of biodegradable plastics and 0.43 million tonnes of bio-based non-biodegradable plastics in 2018 (European Bioplastics 2019). This packaging includes bags for compost, disposable cups, salad bowls, plates, cling film and food containers. Currently the global biodegradable packaging market is estimated at US$ 13.4 billion and is projected to reach US$ 32.7 billion by 2027 (ReportLinker 2020). Furthermore, biodegradable plastics can have useful applications, for example as biodegradable carriers for drug delivery systems and in biodegradable fishing gear to avoid ghost fishing in the long term. In addition, agricultural waste is seen as a source of bioplastics production.

The term "bioplastics" may be misleading. It does not describe either the composition of plastics or their biodegradability. Bioplastics include many materials that are either bio-based plastics (plant-based plastics that can be either biodegradable or non-biodegradable) or biodegradable fossil-based plastics (Tokiwa et al. 2009; Emadian et al. 2017; Norwegian Environment Agency 2018). The bio-based content of bioplastics differs, and the material's actual chemical and physical structure highly affects its biodegradability. At the same time, the different environments in which they are used and/or disposed of, such as soils or the marine environment, play a crucial role in bioplastics biodegradation (Emadian et al. 2017). There are currently different standards and labels indicating the biodegradability and bio-based content of bioplastics, such as International Organization for Standardization (ISO) standards or national and regional standards in the United States and the EU (European Bioplastics 2016).

Evidence collected during the last decade shows that some of the same problems exist with bio-based plastics made from renewable raw materials and with conventional plastics. They can contain toxic additives and contaminants and, while manufactured from plant-based polymers, are not necessarily biodegradable, so that they can fragment into microplastics and persist in the environment for long periods. In the context of recycling, one of the most important disadvantages of bioplastics is that they can contaminate the recycling process if they are not separated from conventional plastics. In most cases the sorting of plastics is based on visual discrimination, which does not distinguish bioplastics from conventional plastics (Basel Convention 2020). A PET-based bottle and a PLA-based (bio-based plastic) bottle, for example, cannot be separated on the basis of their appearance. Mixing PET and PLA fragments during the recycling processes would create problems for the reprocessing unit, as these two materials have different melting points (Alaerts et al. 2018).

Even the presence of biodegradable bioplastics in the industrial compostable process can be highly problematic. To be designated as compostable, plastic has to be 90% degraded after 12 weeks at 60oC. However, in most composting units organic waste is removed after four weeks. If compostable plastic is present, it may not be fully degraded and will contaminate the output (Heinrich Böll Foundation and Break Free from Plastic 2019). There is some evidence that people may not feel the same sense of responsibility to properly dispose of "biodegradable" plastic if they assume it will break down in the environment (GESAMP 2015).

Discarded biodegradable bioplastic bags, like conventional plastic bags, pose risks to aquatic life. A field study comparing the two types of bags when littered found they had similar adverse impacts on infaunal abundance and biogeochemical processes (Green et al. 2015). For bioplastics to be a safe and viable replacement for conventional plastics, their negative environmental impacts during the whole life cycle need to be eliminated.

Bio-based plastics are sometimes reported to have a lower environmental impact than conventional plastics in terms of greenhouse emissions and fossil fuel consumption, but this is not always the case (Chen 2014; Arikan and Ozsoy 2015; Changwichan et al. 2018). There are still debates concerning the full environmental footprint of bioplastics, both biodegradable and non-biodegradable (Vendries et al. 2020). Until now most of the analysis has been limited to carbon dioxide (CO_2) emissions. However, a complete life cycle analysis, including degradation of non-biodegradable bioplastics into microplastics and direct or indirect impacts on land use, could be explored further.

The production of biomass for bio-based plastics can divert land use from the cultivation of food crops or expand cultivation areas into sensitive habitats and environments. The production of 2.11 million tonnes of bio-based plastics in 2019 required approximately 0.79 million hectares of land (0.02% of available agricultural land globally; European Bioplastics 2019). Moreover, it is currently up to twice as expensive to produce bio-based than fossil-based plastics (Pemba et al. 2014; Arikan and Ozsoy 2015; Emadian et al. 2017).

Challenges and solutions for the environmentally sound management of plastic waste in developing countries and socio-economically disadvantaged areas

Plastic waste generation is increasing in developing countries, due in part to greater urbanization and higher economic growth. In 2015 Asia was the largest contributor to global plastic waste, generating 82 million tonnes, while Latin America and Africa each produced 19 million tonnes and Oceania almost 1 million tonnes (Lebreton and Andrady 2019).

Until China banned the import of recyclable waste (among other types of waste) in 2018 (see Chapter 9) it accepted large amounts of plastic waste. Since the Chinese ban there has been an increase in exports of plastic waste to emerging economies. Environmental impacts are therefore being shifted to other countries, where the capacity to manage this waste in an environmentally sound manner may not be comparable (GRID-Arendal 2019). The degree of risk depends on conditions in the receiving region, including environmental laws and regulations, the occupational health and safety of workers, and the type of plastics being processed. Approximately 5-20% of imported plastic waste in emerging economies has no market value, so ends up in landfills and open dumps or is burned (GRID-Arendal 2019).

Rapidly developing economies have been overwhelmed by increasing amounts of plastic waste. They have not been able to keep pace with regard to needed waste management legislation, policies and infrastructure. This problem affects the management of waste generated within these countries as well as that imported from other countries. Low-income countries collect about 48% of waste in cities, but this figure drops to 26% outside urban areas (Kaza et al. 2018). These countries are still heavily dependent on conventional landfilling and practices such as open burning and open dumps.

Improving waste management systems by making basic infrastructure upgrades to replace dumpsites (e.g. with properly engineered and managed landfills) could reduce plastic leakage into the environment. The challenge is that effective waste management systems are expensive, often comprising 20-50% of municipal budgets. Countries need to institute sustainable financing sources for the development of waste management infrastructure and management (Basel Convention 2021). There is also potential for increased global action. Since 2000 the World Bank has committed more than US$ 4.7 billion to support 340 waste management programmes in developing countries (Kaza et al. 2018).

Integrating the informal sector into formal waste management strategies can play a key role in plastic waste management in developing countries. In 2016 the informal sector was responsible for 58% of global plastic waste collection (Lau et al. 2020). The informal sector in India recovers 90% of PET bottles, a percentage much higher than the formal recycling rate for PET plastics in Japan (72.1%), Europe (48.3%) and the United States (31%) (UNEP 2020). In Indonesia a union representing 3.7 million waste pickers is the backbone of plastic waste management. It collects 1 million tonnes of plastic waste per year, 70% of which is recycled (World Economic Forum 2020).

However, informal waste management may present problems for both workers (exposing women, men and children to health problems) and the environment. The work is hazardous, and children are often exposed to danger since informal recycling is commonly practised at the household level, meaning they grow up around waste and informal incineration sites (Wang 2016).

Strategies that are proving effective in improving waste management include implementing a combination of environmental standards, integrating the informal waste sector to create more organized structures (UNEP 2020), and introducing extended producer responsibility (EPR) and deposit-return schemes (UNEP 2018a). Bans and fees on plastic products have also contributed to preventing plastic waste generation in many developing countries. Some of the earliest bans on plastic products include the 1998 ban on purchasing goods in plastic wrappers or bags in Sikkim, India, the 2003 national ban on thin plastic bags in South Africa, and the 2009 ban on polyethylene (PE) bags in Córdoba, Argentina (UNEP 2018b). Bans have led to smuggling of plastic bags in some countries, including Cameroon and Rwanda, although progress is being made on enforcement and compliance (Godfrey 2019).

The absence of recycling programmes and limited access to recycling services are two of the main factors influencing recycling behaviour. For example, the introduction of door-to-door recycling collection in Shanghai, China led to a

Challenges and solutions for plastic waste management in developing countries

Phase	Challenges	Potential solutions
Production phase	Missing or low enforcement of regulation to restrict pollution from pellets during production or transportation.	Adopt and enforce new policies to reduce potential loss of microplastics during transportation and production of plastics.
Consumption phase	High amount of total plastic consumption and plastic waste generation increases the risk of plastic leakage through fly-tipping, littering and unsound waste management.	Improve plastic products design to increase end-of-life management options (reuse, recycling, etc.). Enhance sustainable consumption patterns. Ban/fees on single use plastics.
Waste collection & street cleaning	Inadequate service coverage for waste collection and street cleaning increases direct dumping, open burn practices and escapes of plastics from overflowing waste storage means.	Provide/improve waste collection and street cleaning services and infrastructure. Introduce Extended Producer Responsibility (EPR) and/or drop off collection systems for plastics. Introduce waste collection fees.
Resource recovery	Resource recovery and recycling of plastics is limited due to high costs of separated material, low levels of purity, limited access to recycling services, and a negative perception of recycling systems.	Promote source separation and introduce recycling programmes. Increase awareness of source separation and recycling. Greater involvement in recycling business.
Informal recovery	Much of plastics recovery performed by the informal sector. Causing risks both to the informal sector and the environment.	Integrate the informal waste sector in more organised structures.
Imported waste	Low quality plastics (mixed and/or contaminated) are often imported for recycling. Unwanted plastics are dumped or burned.	Implementation of the Basel Convention Plastic Waste Amendments. Build capacity of custom and enforcement officers, e.g. through trainings.
Drainage & waste water	Poor drainage along with poor waste management leads to uncontrolled transfer of waste during flooding events. Missing or inefficient wastewater treatment plants increase escapes of microplastics from sewage.	Improve drainage and establish regular control and cleaning. Build wastewater treatment plants.
Waste treatment & disposal	Legal management and disposal of plastic waste is limited to low environmental standard recycling facilities and landfilling. Uncontrolled dumping and open burn of plastic waste is still commonplace in many developing countries threatening human health and the environment.	Increase domestic capacity of plastic waste recycling facilities that follow safety and environmental standards. Introduce technological improvements and environmental protection equipment in present facilities. In-place closure of dumpsites. Convert open dumping and burning to controlled dumping or engineered landfills in case of limited budget.

General solutions

- Setting policy goals and regulations to enhance the environmental sound management of plastics waste
- Financing of solid waste management projects by the private sector, global organizations, or municipality fees.

12.5% increase in recycling rates (Zhang et al. 2016). In addition, public perceptions of recycling and commitment by waste management authorities to deliver recycling services influence citizens' engagement in recycling.

To improve waste management, it is critical to build trust within local communities and develop scalability when implementing new technologies, businesses or products. This is best done through local partnerships and messaging targeted to specific groups such as women, men and youth (Ocean Conservancy 2017). It has also been suggested that adopting current, not entirely effective "solutions" from developed countries is not necessarily desirable or possible (Malhotra 2020). For example, there are opportunities in other countries to reduce plastics use and develop alternative home-grown plastic substitutes (e.g. the manufacture of biodegradable plates and bowls from compressed leaves; Kora 2019).

CHAPTER 21

Gender and plastic waste

Women and men can have different perspectives and experiences with regard to resource use and waste management. These different perspectives and experiences may influence both consumption choices and involvement in waste management and recycling. While women tend to be visibly involved at the household level – as recycling activists and participants in informal recycling activities – they tend to be under-represented in formal employment in the waste management and recycling sector (UNEP-COBSEA-SEI 2019). Understanding gendered influences on behaviour and attitudes in different cultures can lead to more effective policymaking and promote the involvement of women along the waste management and recycling value chain. Greater formal engagement of women in the waste management sector could significantly contribute to the fight against plastic pollution.

At the household level, women are often the main decision-makers when it comes to household purchases. Their consumption patterns can influence, for example, the development and production of alternatives to plastics, plastic products with fewer additives, and other improvements in plastic products (UNEP-COBSEA-SEI 2019). As informed consumers, women are more likely to be involved in the prevention of plastic pollution, demanding zero or minimal plastics or alternative packaging for consumer goods (Ocean Conservancy 2019).

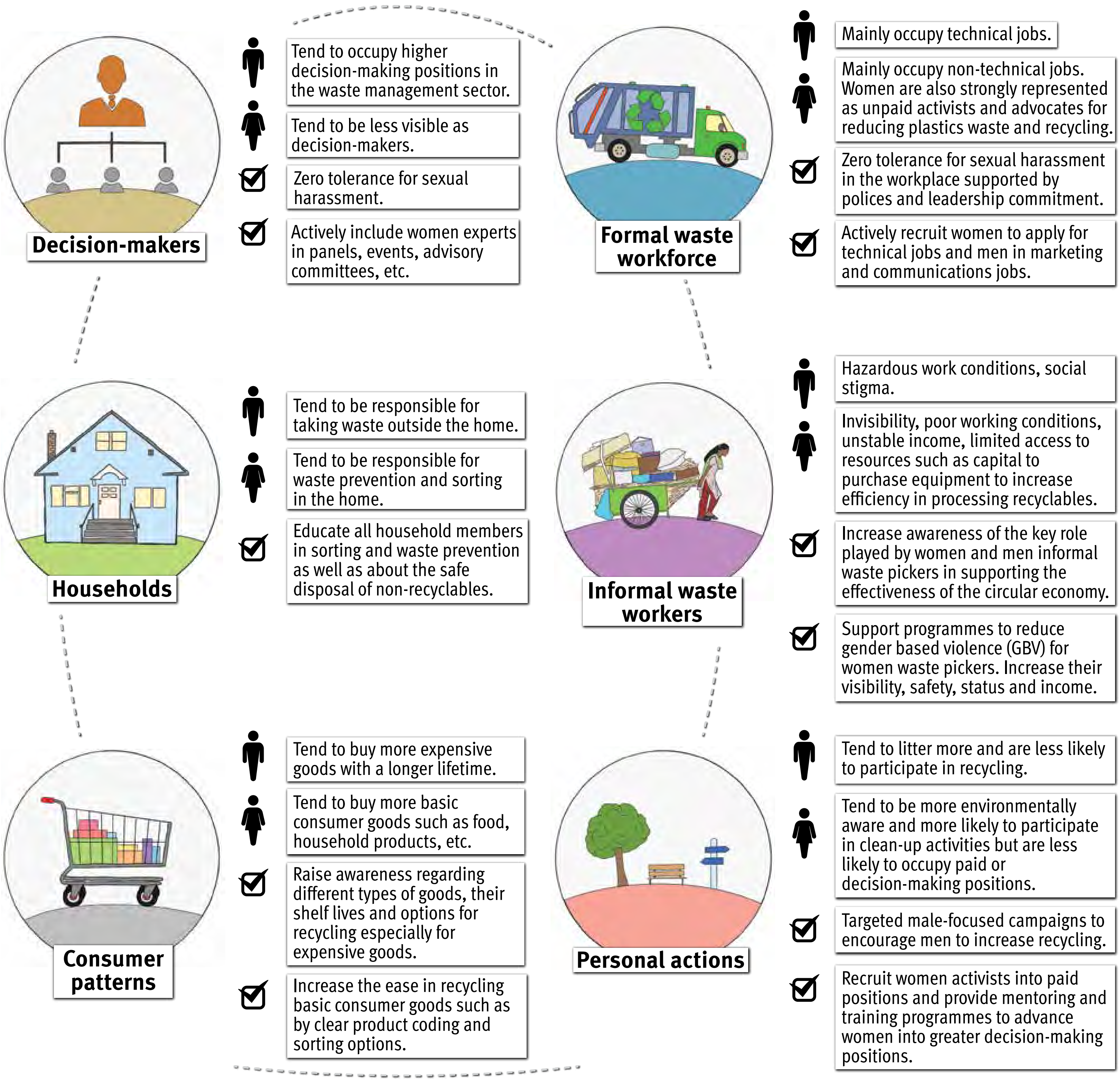
Studies indicate that women are often responsible for domestic waste management and more likely to engage in household recycling activities (UNEP-IETC and GRID-Arendal 2019). In Bhutan, Mongolia and Nepal men were found less likely to participate in household recycling programmes and more likely to play the role of simply disposing of household waste (UNEP-IETC and GRID-Arendal 2019). A survey in Indonesia found that men self-identified as litterers, while women self-identified as proper disposers (GA Circular and Ocean Conservancy 2019).

A traditional gendered division of labour exists throughout the waste management and recycling value chain globally (Aidis and Khaled 2019). Women are represented in the greatest numbers at the base of the recycling chain, most often as informal waste pickers and sorters of recyclables, with limited upward mobility. For example, in Pune, India, 90% of street recycling pickers in 2012 were women (Chikarmane 2012) and in Arequipa, Peru, 80% of waste pickers were women (Aidis and Khaled 2019). "Men's work" is typically associated with heavy lifting and thus higher wages. Women have less access to equipment, vehicles and waste than men; consequently, they are less able to access, collect and transport larger volumes and higher-value recyclables. Informal women waste collectors work under challenging physical conditions; they are threatened with danger to their safety and health (WECF 2017), violence, harassment and exploitation. These women lack secure employment, wages, legal protection and any recourse or representation (Aidis and Khaled 2019).

In the formal waste management and recycling sector women are under represented, with several notable exceptions. They tend to occupy communications and administrative positions, but are less likely to work in management or technical fields (Godfrey et al. 2018). Women are also strongly represented in time-consuming activities that necessitate precision, such as sorting and separating materials into clean, uncontaminated streams. Men are more likely to be represented in activities that require physical strength and some technical knowledge, such as driving dump trucks and loading and unloading waste (GA Circular and Ocean Conservancy 2019). According to a pioneering global survey of women in the waste management sector, more than 50% of those participating in the survey worked in waste prevention, reuse, repair, refurbishment and recycling (Godfrey et al. 2018). The growing global paradigm shift towards valuing waste as a resource, and the move away from landfilling towards waste prevention, reuse, recycling and recovery are likely to lead to more employment opportunities for women (Godfrey et al. 2018).

Women are under-represented in decision-making positions in waste management. Men are employed mostly in

Gender and plastic waste management



institutions and central authorities that set priorities and make decisions about municipal waste infrastructure, while women are highly involved only at the local level. Promoting women as leaders and entrepreneurs could lead to more women taking part in decision-making processes (UNEP-IETC and GRID-Arendal 2019).

Sexual harassment and abuse are significant issues affecting women and inhibiting their advancement all along the recycling value chain (Aidis and Khaled 2019). Enterprises and organizations in the formal sector often do not incorporate any recourse for on-the-job sexual harassment and abuse of power affecting female workers, which inhibits their ability to engage in other functions in the value chain.

The absence of data in general, and of sex-disaggregated data, is a widely acknowledged challenge throughout the waste management and recycling sector globally (Aidis and Khaled 2019). It severely undermines the visibility and contributions of women in this sector, while inhibiting the ability of governments, donors and other stakeholders to track and benchmark change. There is also a need for targeted research and data specifically concerning marine plastics and gender.

The Basel Convention – a global, legally binding instrument to address plastic waste

The overarching objective of the Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and their Disposal is to protect human health and the environment against the adverse effects of hazardous and other wastes. The provisions of the Convention centre around the following principal aims:

- the reduction of generation and the promotion of environmentally sound management of hazardous and other wastes requiring special consideration, wherever the place of disposal;
- the restriction of transboundary movements of hazardous and other wastes except where it is perceived to be in accordance with the principles of environmentally sound management;
- a regulatory system applying to cases where transboundary movements are permissible based on a Prior Informed Consent (PIC) procedure.

In 2019 the Conference of the Parties decided to enhance control of plastic waste by amending Annexes II, VIII and IX to the Convention through the so-called Plastic Waste Amendments, making the Convention the only global legally binding instrument to specifically address plastic waste. From 1 January 2021, 186 States and one regional economic integration organization around the world are bound by the amendments. The amendments clarify the categories of plastic waste falling within the scope of the Convention and with respect to which proposed transboundary movement must take place in accordance with the PIC procedure.

With regard to the transboundary movements of waste, the Convention differentiates between three types of waste. The Plastic Waste Amendments introduced new entries to each of the affected Annexes:

- Annex II lists categories of wastes requiring special consideration. The new entry covers all plastic waste, including mixtures of plastic waste, except those covered in the other Annexes;
- Annex VIII lists wastes that are characterized as hazardous. The new entry covers hazardous plastic waste;
- Annex IX lists wastes that are not considered hazardous. The new entry covers plastic waste that is not hazardous provided the waste is destined for recycling in an environmentally sound manner and almost free from contamination and other types of wastes.

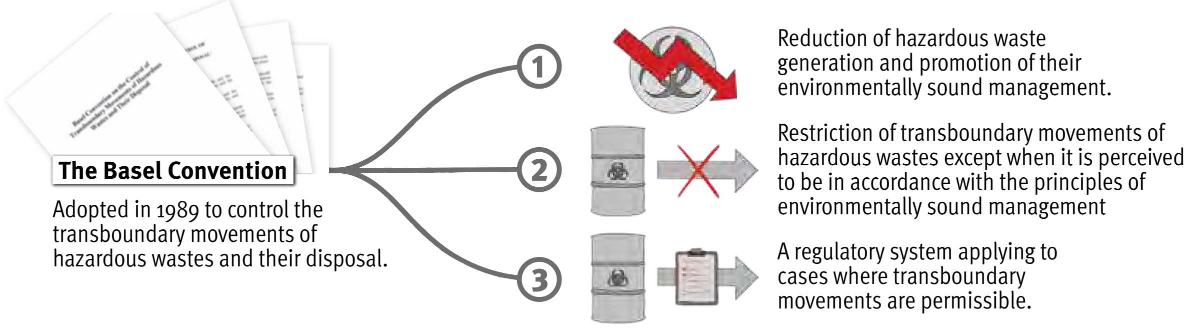
The Basel Convention Plastic Waste Amendments imply that all plastic waste and mixtures of plastic waste generated by Parties to the Convention, and which are to be moved to another Party are subject to the Prior Informed Consent procedure unless they are non-hazardous and destined for recycling in an environmentally sound manner and almost free from contamination and other types of waste. This procedure requires the Parties to the Convention to ensure the environmentally sound management of exported waste. It includes the following stages:

- notification by the exporting country;
- consent and issuance of a movement document;
- transboundary movement;
- confirmation of disposal.

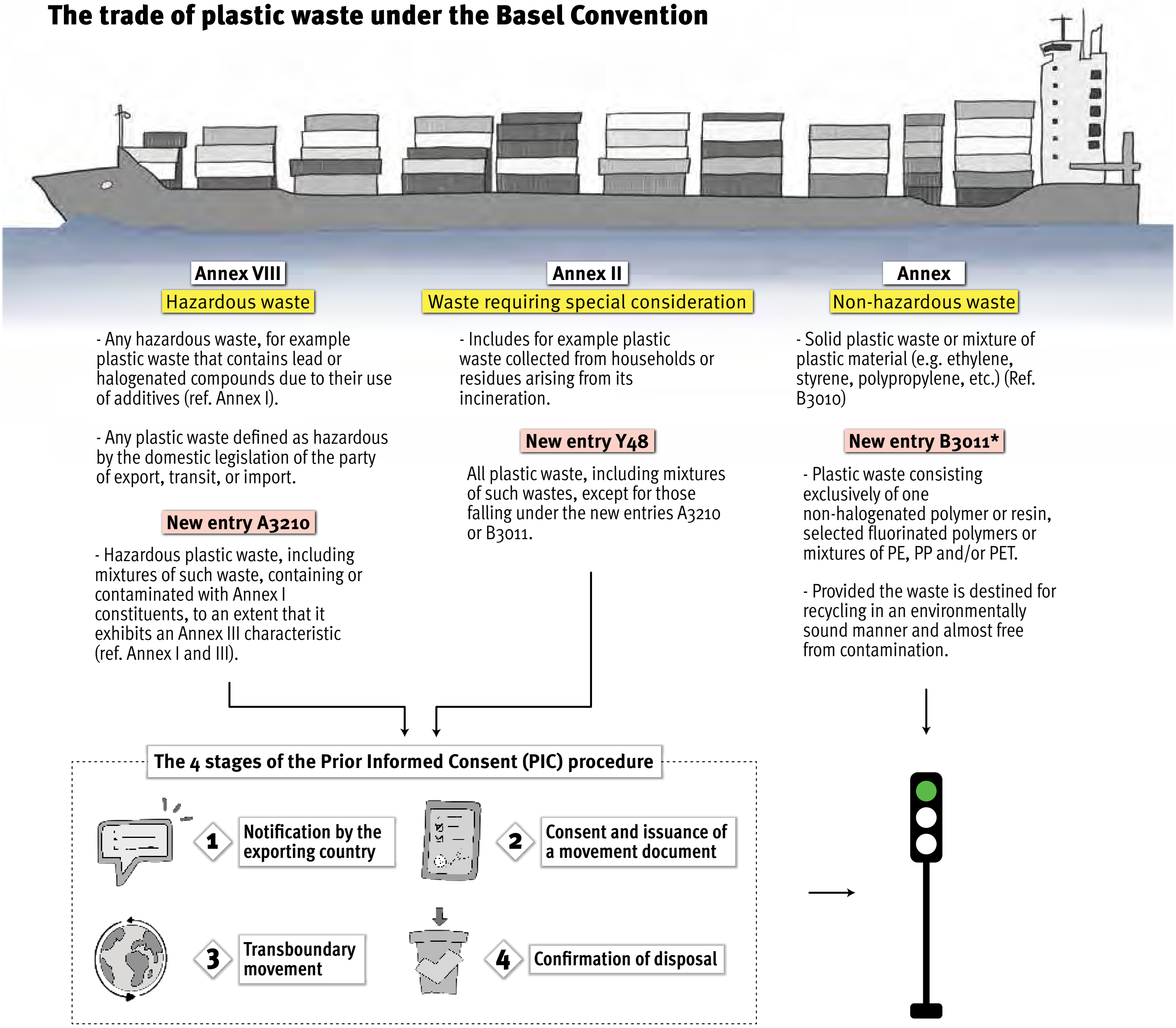
The specified categories of plastic wastes are also subject to the Convention's provisions pertaining to waste minimization and environmentally sound management. The Plastic Waste Amendments are therefore expected to have a range of positive impacts across the three pillars of the Basel Convention, namely:

- Increased control of transboundary movements (TBM): By establishing a legally binding framework for the trade in plastic waste, the Plastic Waste Amendments create the conditions for the global trade in plastic waste to become more transparent and better regulated;
- Increased environmentally sound management (ESM): By ensuring that the Convention's provisions on ESM now apply to specified categories of plastic waste, the Amendments provide a powerful incentive to strengthen

The Basel Convention



The trade of plastic waste under the Basel Convention



*Three new entries related to the Plastic Waste Amendments (BC14/12)

Source: Basel Convention (2021c). Illustration by Levi Westerveld / GRID-Arendal (2020).

national infrastructures for the collection, recycling and final disposal of plastic waste;

- Increased waste prevention and minimization: By bringing the listed types of plastic waste under the Convention's provisions pertaining to waste prevention and minimization, the Amendments will help create jobs and economic opportunities, not least by incentivizing innovation, such as in the design of alternatives to plastic and in the phasing out of hazardous additives.

In addition, the Basel Convention´s Ban Amendment entered into force the same year. For those Parties bound by it, the Ban Amendment prohibits transboundary movements of hazardous wastes covered by the Convention that are intended for disposal operations from members of the Organisation for Economic Co-operation and Development (OECD), the EU and Liechtenstein to all other countries (Basel Convention 2021a and b).

Sharing the common objective of protecting human health and the environment from hazardous chemicals and wastes, the Basel Convention and the Stockholm Convention on Persistent Organic Pollutants (POPs) also have synergies with regard to plastic waste.

Plastic waste may contain various POPs, such as some brominated flame retardants and short-chain chlorinated paraffins (see Chapter 3 on additives). The leaching out of POPs from plastic particles may have significant adverse effect on the health of both terrestrial and marine wildlife. Plastic debris can also adsorb POPs such as polychlorinated biphenyls (PCB), DDT and dioxins which, if ingested, exhibit a wide range of adverse chronic effects in marine organisms. The Stockholm Convention controls various POPs which have been used as additives, flame retardants, plasticizers in plastics or manufacture of fluoropolymers.

In early 2021 the POPs Review Committee (POPRC), which is a subsidiary body responsible for reviewing POPs for listing in the Stockholm Convention, found that UV-328, which is a high-volume additive in plastic products such as personal care products and coatings, satisfies all the criteria set out in Annex D, namely persistence, bioaccumulation, potential for long-range environmental transport and adverse effects to humans and/or the environment. UV-328 was found in the environment and biota, including in remote areas such as the Arctic and the Pacific Ocean, far from its production and use. UV-328 has been found to be transported with, and may subsequently be released from plastic debris, which is taken up for example by seabirds with subsequent accumulation in their tissue. Taking into account the recommendations of the Committee, a future Conference of the Parties could trigger its reduction or elimination. Such a listing would strengthen the Stockholm Convention's role as a key global instrument to tackle the plastic waste crisis.

CHAPTER 23

National policies

The prevention of marine litter and plastic pollution requires a complexity of national interventions across multiple government agencies that go beyond developing effective waste management processes (Raubenheimer and Urho 2020). Policies and regulations must target multiple actors along the product value chain and consider, at a minimum, compliance, enforcement, prevention, collection, sorting, treatment, resource and process efficiency, transparency, innovation and, importantly, environmental protection (Basel Convention 2013). National polices also give effect to commitments undertaken by countries when they sign global treaties and other multilateral agreements.

Monitoring marine litter and plastic pollution can assist in understanding sources and pathways (see Chapter 26), allowing for improved design of national policies through an evidence-based approach, as well as the evaluation of the effectiveness (including enforcement) of existing policy and regulatory frameworks. Evaluation is supported by the development of indicators (Basel Convention 2013).

National policies to prevent marine litter and plastic pollution can support the implementation of the waste hierarchy, targeting prevention; minimization; reuse; recycling; other recovery, including energy recovery; and final disposal. Additional benefits of implementing this waste hierarchy are the minimization of pollution by chemicals used to manufacture products, reducing the contribution of waste to climate change (CIEL 2019a and b), improving resource efficiency (OECD 2019a) and enhancing livelihoods (Basel Convention 2019b), particularly in the informal sector, which tends to be dominated by women (GA Circular 2019).

To facilitate increased rates of reuse, repair and recycling, national policies must ensure adequate financing mechanisms are available to support collection and sorting in the long-term (Ocean Conservancy 2019). In addition, policies aim to create sustainable end-markets (Basel Convention 2019b) by driving supply and demand for recyclable materials (see below). This will promote investment by the private sector in solid waste management, alleviating the financial burden on local governments (OECD 2018).

Eco-design is a key component of effective waste management (Basel Convention 2019b). Where products are designed for reuse and repair, the rate of waste generation can be reduced. Products designed for recyclability are more likely to retain end-of-life value on domestic or international markets (OECD 2018), incentivising collection and diverting these wastes from incineration or landfill. Policies can incentivize eco-design through higher taxes for non-compliant designs, or legislation that mandates eco-design principles such as extended producer responsibility (EPR) legislation and the EU Ecodesign Directive (EU 2009).

Products that are harmful to human health or the environment, or that do not meet eco-design criteria, may be considered for elimination from domestic markets (Raubenheimer and Urho, 2020). This can be achieved through voluntary phaseout with industry or outright bans. Examples include microbeads in cosmetics, plastic bags and other problematic single-use items (Ocean Conservancy 2019). Important considerations when designing such policies are the local socio-economic circumstances, as well as compliance and enforcement measures.

Per capita consumption can also be reduced through product taxes, commonly applied to the producer that places the product on the market, or to the consumer at the point of sale. The resulting increase in product price acts as a disincentive for purchase, thereby reducing consumption (Nielsen et al. 2019; Thomas et al. 2019). Tax rates can also be eco-modulated. By placing higher taxes on products that do not adhere to eco-design principles, the relatively lower tax rate for products that are more manageable at end-of-life would encourage producers to redesign products that meet the lower tax criteria in order to save on costs (OECD 2019b).

Reuse can be implemented through systems of return, thereby reducing consumption of new products. This may require separate collection systems, often involving retailers in providing temporary storage facilities. Such systems commonly include a deposit scheme to incentivize return by consumers.

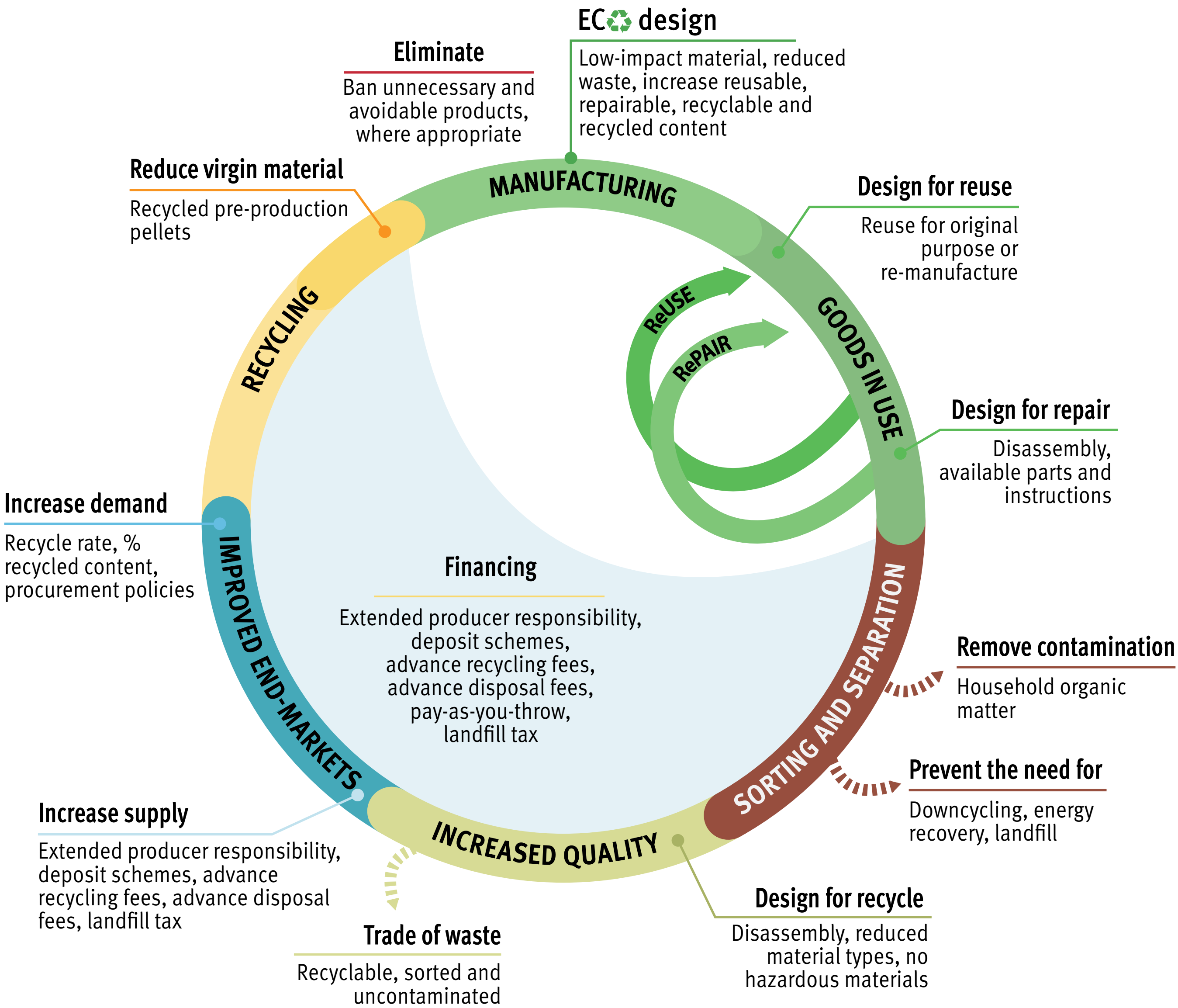
Similarly to reuse, promoting design for repair may require restructuring of current processes. Authorized repair centres may be necessary, and spare parts and instructions on dismantling and repairing products will need to be made readily available. Both reuse and repair will reduce the consumption of new products by extending the longevity of existing products.

Supply and demand

Underpinning policies that promote increased recycling rates is the creation of end-markets for recyclable materials (Basel Convention 2019b). Firstly, the supply of quality recyclable material to the market must be promoted (OECD 2018). Improvements to quality can be achieved by reducing contamination of recyclable materials, beginning with source separation (Basel Convention 2019b). In households and commercial premises, organic matter and non-recyclables should be removed from collection streams intended for sale to recycling facilities (Ocean Conservancy 2019).

Secondly, waste diverted from incineration and landfill increases the quantity of recyclable waste returned to the economy. Demand for recyclable materials can be driven through, for example, government procurement policies that stipulate minimum recycled content in infrastructure projects (OECD 2018). Voluntary industry commitments with regard to recycled content can be encouraged, progressing to mandatory targets as appropriate.

National policies towards circularity



Illustrated by GRID-Arendal (2021).

Finance mechanisms

Various mechanisms have been employed by governments to assist in financing waste management, including (Basel Convention 2019a and b; Ocean Conservancy 2019):

- *deposit schemes:* incentivize consumers to return items to collection points;
- *advanced recycling fees:* producers contribute to the cost of treatment of their products at end-of-life, often combined with a labelling scheme to inform consumers;
- *extended producer responsibility (EPR) schemes:* promote eco-design and financial contributions by producers to end-of-life treatment of their products;
- *advance disposal fees:* consumers pay for collection and disposal services at the time of purchase, often applied to bulky white goods;
- *pay-as-you-throw:* special garbage bags or tags/stickers are purchased and non-compliant bags are not collected through the scheme;
- *landfill taxes:* generate income and promote diversion of waste back into the economy.
- *tourism, hospitality and leisure taxes:* these contribute to managing the significant volumes of waste generated by this sector.

Research has shown that individual policy interventions cannot solve the increasing problem of plastic waste. Instead, a complementary and systemic suite of interventions that target the entire plastics value chain across sectors is needed to achieve an 80% reduction in marine plastic pollution inputs while gaining the co-benefits of government cost savings, job creation, and a reduction in greenhouse gas emissions (Pew Charitable Trusts and SYSTEMIQ 2020).

CHAPTER 24

Global responses through UNEA resolutions

The United Nations General Assembly (UNGA) recognized the link between waste management and the protection of the environment in a resolution adopted in 1989 (UNGA 1989b). In the same year concern was expressed about the risk to living marine resources from lost or discarded large-scale pelagic driftnets (UNGA 1989a). In 2002, 2005 and 2008 the impact of derelict fishing gear on habitats and marine living resources was again recognized (UNGA 2002, 2005a and c, 2008b). The 2005 resolution (UNGA 2005a) was supported by a UNEP report titled "Feasibility Study on Sustainable Management of Marine Litter". This report identified both land- and sea-based sources of litter and detailed measures to prevent and clean up debris (UNGA 2005b). Cooperation was called for, in recognition of the global nature of the problem.

Recycling, reuse, reduction, and economic incentives were encouraged in 2008 (UNGA 2008a). More recently, concern was again expressed about the negative effects of marine litter and microplastics on the health of the oceans and marine biodiversity, specifically noting plastics (UNGA 2015). A number of national preventive measures were also encouraged.

The United Nations Environment Assembly (UNEA) was created in 2012 as the world's highest level decision-making body on the environment. Resolutions on marine litter and microplastics were adopted at each meeting in 2014, 2016, 2017 and 2019. Resolutions in both UNGA and UNEA are adopted by consensus, demonstrating the importance of the issue to all countries and the desire to find solutions at scale. Resolutions are voluntary and rarely set binding targets or timelines. However, at the third UNEA meeting an overarching goal was set for the long-term elimination of discharge of litter and microplastics to the oceans (UNEA 2017). This builds on the first global goal, set in 2012, to achieve significant reductions in marine debris by 2025 (UNGA 2012).

Some key components of global governance of marine litter and microplastics have been discussed at UNEA. Principles to guide action have progressed from the precautionary approach (Res. 1/6), sustainable consumption and production and the polluter pays principle (Res. 2/11) to preventive action, reduction and resource efficiency (Res. 3/7), circularity (Res. 4/6), and resource-efficient design, production and use (Res. 4/9).

International and regional governance has included calls for regional action plans and an urgent global response to addresses the product life cycle (Res. 2/11 and 4/9). The need for common definitions and harmonized standards and methodologies for monitoring has been recognized (Res. 3/7), as well as the need for coherence and coordination among existing mechanisms (Res. 4/7).

National implementation has been promoted through measures such as resource efficiency by governments and industry and addressing materials at source (Res. 4/7). Legislation and enforcement are encouraged, together with awareness-raising and beach clean-ups (Res. 1/6). Phasing

UNGA

1989	2002	2005	2008	2015
Lost or discarded large-scale pelagic driftnets Waste management	Impact of derelict fishing gear	Impact of derelict fishing gear Waste management	Impact of derelict fishing gear Recycling, reuse, reduction, economic incentives	Negative effects on oceans & marine biodiversity, specifically by plastics

UNEA

	2014 (Res. 1/6)	2016 (Res. 2/11)	2017 (Res. 3/7)	2019 (Res. 4/6)	2019 (Res. 4/9)
Principles	Precautionary approach	Sustainable consumption & production Polluter pays	Prevention Reduction Resource efficiency	Circularity	Resource-efficient design, production and use
International, regional governance		✓	✓	✓	✓
National Implementation	✓	✓	✓	✓	✓
Cooperation & coordination	✓	✓	✓	✓	✓
Information	✓	✓	✓	✓	✓
Funding		✓	✓	✓	✓
Education & Awareness	✓	✓	✓	✓	✓
Stakeholder engagement		✓	✓	✓	✓

Key requests by UNEA

2014 (Res. 1/6)	2016 (Res. 2/11)	2017 (Res. 3/7)	2019 (Res. 4/6)	2019 (Res. 4/9)
Study: Sources, measures & recommendations for most urgent actions & research **Facilitate** regional & national action plans	**Study:** Effectiveness of relevant international, regional & subregional governance strategies & approaches **Facilitate** action plans	**Convene** AHEG to examine barriers & options **Facilitate** regional & national action plans **Strengthen** UNEP input to the GPML	**Strengthen** scientific & technological knowledge: Compile data & information Recommend indicators Gather information to inform policies & action Establish a multi-stakeholder platform Develop guidelines for the sustainable use & production of plastics **Extend AHEG mandate** to: Take stock of existing activities. Identify technical & financial resources. Encourage partnerships. Analyse effectiveness of response options	**Support** national & regional action plans **Facilitate** technical & policy support

Global Visions

2012	2015	2017	2018	2019
Significant reductions in marine debris by 2025 (UNGA RES/66/288)	Prevent & significantly reduce marine debris by 2025 (SDG 14.1)	Long-term elimination of discharge of litter & microplastics into the oceans (UNEA Res 3/7)	A resource-efficient & sustainable approach to the management of plastics (Ocean Plastics Charter)	Reduce additional pollution by marine plastic litter to zero by 2050 (Osaka Blue Ocean Vision)

out of microplastics and identifying cost-effective preventive measures are needed, as well as reductions in derelict fishing gear and dumping of litter at sea (Res. 2/11). The importance of increased collection and recycling rates, re-design and re-use, and avoiding unnecessary plastics and chemicals of concern have been stressed, as well as addressing microplastics from sea-based sources (Res. 3/7, 4/7 and 4/8). Product design has been called for to reduce the release of microplastics and to improve waste management (Res. 4/6 and 4/7), along with sound management of chemicals and waste (Res. 4/8). Business models should take into account the environmental impact of single-use plastics (Res. 4/9).

To fund national action, public-private partnerships (Res. 2/11), deposit-refund systems, and extended producer responsibility schemes (Res. 2/11, 3/7, 4/7 and 4/9) have been suggested. Financial assistance for developing countries has been encouraged in order to implement necessary policies, regulatory frameworks and measures consistent with the waste hierarchy (Res. 2/11). However, it has been recognized that cost-effective technology and effective measures already exist (Res. 3/7).

The request for information has progressed from the source, fate and impact of microplastics (Res. 1/6) to identifying hotspots and understanding associated chemicals, social and economic impacts (including human health). Compatible standards for monitoring and assessment are needed, together with harmonized international definitions (Res. 2/11), supported by indicators (Res. 3/7). Key sectors across the value chain are called upon to provide information on the impacts of their products throughout the life cycle (Res. 3/7). A strengthened science-policy interface is also promoted (Res. 4/6). Importantly, it was recognized at the second UNEA meeting that research already provides sufficient evidence of the need for immediate action (Res. 2/11).

Cooperation and coordination have been key themes of the five resolutions, including sharing of best practices. Stakeholder engagement across the life cycle, including relevant industry sectors and civil society, has also been a consistent theme. UNEA invited relevant international and regional organizations and conventions including, among others, the Basel and Stockholm Conventions (as appropriate and within their mandates) to increase their action to prevent and reduce marine litter and microplastics and their harmful effects and to coordinate, where appropriate, to achieve that end.

Awareness-raising has progressed from a general request (Res. 1/6), to awareness of the sources, negative effects and reduction measures (Res. 2/11), to including the private sector and civil society in awareness-raising (Res. 3/7) and awareness of sustainable consumption and production (Res. 4/6).

Resolutions have also requested UNEP workstreams to progress global discussions on marine litter and microplastics. At the first meeting (UNEA 1), a study was requested which would identify key sources, possible measures and recommendations for the most urgent actions and research needs (UNEA 2014). At the second meeting (UNEA 2), a study was requested to analyse the effectiveness of relevant international, regional and subregional governance strategies in combating marine plastic litter and microplastics (UNEA 2016). The third meeting (UNEA 3) requested facilitation of the development and implementation of marine litter action plans and the convening of an ad hoc open-ended expert group (AHEG) to examine barriers to and options for combating marine plastic litter and microplastics from all sources (UNEA 2017). This expert group was extended at the fourth meeting (UNEA 4) to take stock of existing actions, identify technical and financial resources, encourage partnerships, and analyse the effectiveness of response options (UNEA 2019). Also at the fourth meeting, a supporting body, the Scientific Advisory Committee (SAC), was established to provide scientific support to the AHEG.

CHAPTER 25

Other global and regional initiatives relevant to marine litter

The Basel Convention is the only global legally binding instrument that specifically addresses plastic waste (see Chapter 22). The Stockholm Convention regulates a number of POPs used as plastic additives. Other chemicals not covered under the Stockholm Convention are considered under a voluntary initiative, the Strategic Approach to International Chemicals Management (SAICM). However, because marine plastic litter has impacts across many marine sectors, numerous other global and regional bodies have policies and initiatives that, to varying degrees, include the control of marine litter. A recent report (Karasik et al. 2020) lists 28 global policies that have emerged in the last 20 years which address marine pollution However, few of these policies specifically address plastic pollution or have targets or legally binding commitments to address that issue (especially in relation to land-based sources of marine litter). The current global governance processes are supported by scientific initiatives such as the Group of Experts on the Scientific Aspects of Marine Environmental Protection (GESAMP), which helps guide further policy development (GESAMP 2021).

The United Nations Convention on the Law of the Sea (UNCLOS) is the most comprehensive treaty covering the world's oceans. While marine plastic litter had not been identified as a problem when UNCLOS was drafted, Part XIII does cover protection of the marine environment from a broad range of sources. Specific pollutants are not listed, but the obligations of UNCLOS can be interpreted to include plastic pollution that originates from the sources identified in the agreement (UNCLOS 1982). Importantly, UNCLOS also calls upon signatories to endeavour to establish global and regional rules and standards to protect the marine environment (Goncalves and Faure 2019).

There are currently three legally binding global instruments in addition to the Basel and Stockholm Conventions that explicitly regulate some aspect of marine plastic litter in addition to other wastes. These are Annex V of the International Convention for the Prevention of Pollution from Ships (MARPOL), the 1972 Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter (the London Convention), and its 1996 Protocol (the London Protocol).

Signatories to MARPOL Annex V are legally bound to ensure that plastic and other pollutants are not discharged into the sea, and there are protocols for rubbish disposal. Plastic rubbish can be delivered to a port waste facility or incinerated onboard. All ships are obliged to keep a garbage record book or logbook detailing all disposal and incineration operations (IMO 2020). The London Convention and Protocol, unlike MARPOL, are generally concerned with direct disposal of land generated waste dumped at sea such as dredged materials (Nauke and Holland 1992). Under the London Protocol, the most recent of the two treaties, any dumping of wastes at sea is prohibited with the exception of certain waste categories and only following a strict assessment procedure (including waste prevention audits) and issuance of a permit. However, the Contracting Parties to the London Convention and Protocol have recognized the potential for plastic pollution, especially microplastics, associated with some of the waste stream and the need to redouble efforts to prevent plastics to enter the marine environment through such wastes. In addition to these three conventions, in 2018 the International Maritime Organization (IMO) adopted a global action plan to address marine plastic litter from ships.

The Convention on the Conservation of Migratory Species of Wild Animals (CMS) aims to protect migratory seabirds. It includes a commitment to control marine pollution, but does not include any specific actions to protect these species from marine plastic litter (Goncalves and Faure 2019). Nevertheless, two action plans have been adopted for the protection of whales and turtles from marine litter, and for the protection of loggerhead turtles in the Pacific region.

Some globally binding instruments include measures that do not explicitly regulate, but rather infer the regulation of marine litter and plastic pollution, such as the CMS, the Convention on Biological Diversity (CBD) and the Agreement for the Implementation of the Provisions of the United Nations Convention on the Law of the Sea of 10 December 1982 relating to the Conservation and Management of Straddling Fish Stocks and Highly Migratory Fish Stocks (the United Nations Fish Stocks Agreement). The latter requires the minimization of pollution, as well as catch by lost or abandoned fishing gear, which includes all synthetic gear (UN Fish Stocks Agreement 1995). Minimizing catch by such gear is also promoted in the voluntary FAO Code of Conduct for Responsible Fisheries.

Global and regional initiatives to combat plastic pollution

	Land-based	Ocean		Binding
Pollution prevention and protection	Source of 80% of marine litter	National Jurisdiction (NJ)	Areas Beyond NJ	
Basel Convention	■	■		yes
Stockholm Convention	■	■	■	yes
UN Convention on the Law of the Sea	■	■	■	yes
MARPOL Annex V		■	■	yes
London Convention		■		yes
London Protocol		■	■	yes
Global Programme of Action	■	■		no
Regional Seas Action Plans	■	■		no*
SACIM	■	■	■	no
Biodiversity and species focus				
Convention on Biological Diversity	■	■	■	yes
Convention on Migratory Species	■	■	■	yes
UN Fish Stocks Agreement		■	■	yes
FAO Code of Conduct for Responsible Fisheries		■	■	no

*Except the Mediterranean

Sources: UNEP (2017), Goncalves and Faure (2019). Illustrated by GRID-Arendal (2021).

Global initiatives that address land-based sources of litter (the main source of marine plastic) are generally non-binding. They include the Global Programme of Action for the Protection of the Marine Environment from Land-based Activities (GPA) (UNEP 1995). Related initiatives include the Global Partnership on Marine Litter (GPML), which introduced the Honolulu Strategy in 2011 to tackle marine debris. While there are no legally binding commitments or targets in the Honolulu Strategy, there are goals and strategies to reduce the amount and impact of marine litter from land-based and sea-based sources. The Honolulu Strategy acts as a framework to guide national action.

According to Karasik et al. (2020), only two international policies set targets to reduce the amount of plastic entering the marine environment. Aichi Biodiversity Target 8, adopted by the Parties to the Convention on Biodiversity (CBD) in 2010, aims to reduce pollution (the inclusion of plastic is implied) to levels that are not detrimental to ecosystem function and biodiversity by 2020 (CBD 2011). As this target has not been met, the CBD has undertaken the development of a post 2020 global framework to be adopted in 2021. The other target is included in United Nations Sustainable Development Goal (SDG) 14, which states "…by 2025, prevent and significantly reduce marine pollution of all kinds, in particular from land-based activities, including marine debris" (United Nations 2015). A more recent global target was adopted in 2017 at the third meeting of the United Nations Environment Assembly, during which Member States agreed to the long-term elimination of discharge of litter and microplastics into the oceans (UNEA Res. 3/7).

Numerous regional initiatives address marine plastic litter. Foremost of these are the action plans of the UNEP Regional Seas Programme. The Regional Plan on Marine Litter Management in the Mediterranean is binding on Member States, while voluntary action plans have been adopted by another 12 Regional Seas and three additional Regional Seas are in the process of preparing such plans. Other regional marine litter action plans adopted include the APEC and ASEAN regions, as well as the G7 and G20.

A number of EU directives are aimed at reducing marine litter. The most important is the Marine Strategy Framework Directive (MSFD) (European Union 2008), an integrated policy designed to achieve Good Environmental Status (GES) of the European marine environment by 2020. GES is defined by 11 descriptors including D10 – properties and quantities of marine litter do not cause harm to the coastal and marine environment. Other EU directives relevant to marine litter include the Single-Use Plastics Directive and the Port Reception Facilities Directive. The latter requires all waste, including waste collected in nets, to be placed in port reception facilities (European Union 2020).

A number of private-public partnerships have been established to tackle plastic litter at the source. They include the New Plastics Economy Global Commitment, led by the Ellen MacArthur Foundation and UNEP. This partnership, which includes many businesses that make or use plastic packaging, aims to eliminate unnecessary packaging, improve recycling, reuse and disposal technology, and encourage circularity of plastic resources. Others include NextWave, a coalition of companies committed to reuse plastic which might otherwise end up in the ocean; the Alliance to End Plastic Waste, a network of companies and communities working to develop innovative solutions to combat plastic waste; and Fishing for Litter, a project that encourages fishers to collect marine litter, to name a few. Plastics Pacts have been agreed through the Plastic Pact Network (see Chapter 16) in a number of countries, including Canada, Chile, France, the Netherlands, Poland, Portugal, South Africa, the United Kingdom and the United States. There are regional pacts in Europe and Australia, New Zealand and the Pacific Islands. These pacts set local targets and bring together industry, government, NGOs and citizens to achieve these aims.

A myriad of actions are being taken by governments, individuals and non-governmental organizations (NGOs) to combat the growing plastic litter problem, but they are fragmented and indications are that, in many places, plastic pollution is increasing. Recent assessments of global, regional and subregional approaches to the problem document limitations in scope, mandate and application (UNEP 2017; Dauvergne 2018). Some industries also actively push back against change, resisting regulation and accountability, which means success will require strong, coordinated and concerted intervention (Dauvergne 2018; da Costa et al. 2020). In response, proposals have been made for the establishment of a binding multilayered global approach (UNEP 2017).

CHAPTER 26

Monitoring and assessment

Because marine plastic litter is transported by wind, waves and currents, it can traverse national ocean boundaries, spreading the problem well beyond the source. A recent report by the Basel Convention (GRID-Arendal 2020) identified 53 global and 33 regional initiatives established to address this type of litter. Many of these initiatives are designed to support the integration of individual litter assessments within a larger geographic region and to identify synergies

The importance of monitoring and assessment

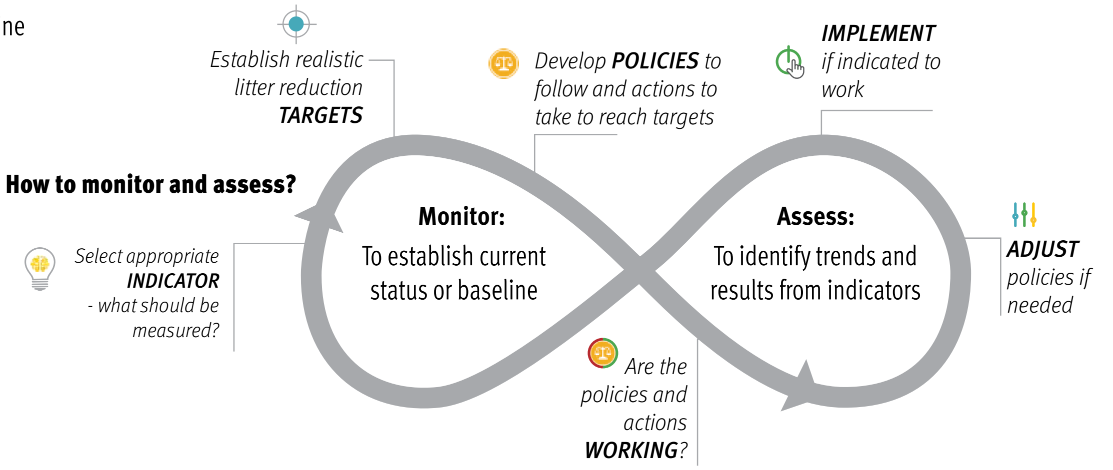
Developing indicators, setting targets and taking action

1. Why monitor and assess?

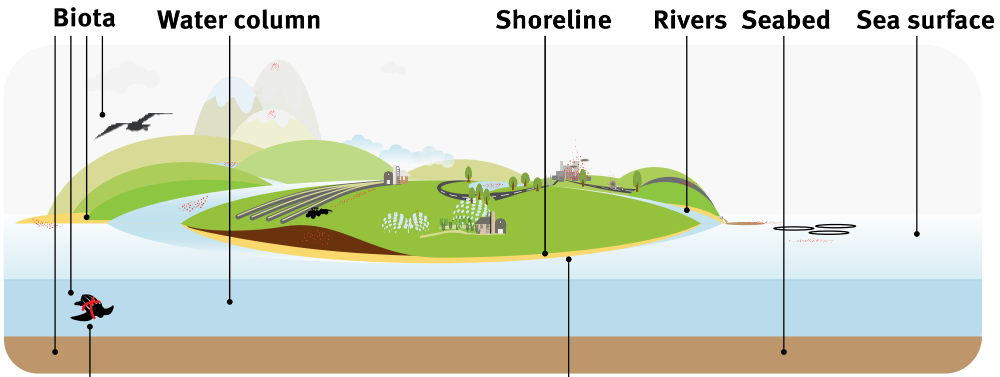
To reduce the inflow and impact of marine plastic litter by identifying

the SOURCE,
the TYPE and
the FATE

2. How to monitor and assess?



3. Where?



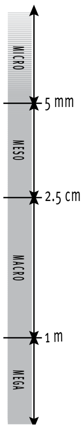
Document impact - for example entanglement of turtles and seabirds' ingestion of plastic litter

Count specific items - for example bottles per linear meter of beach length (e.g. 100 linear metre)

4. What?

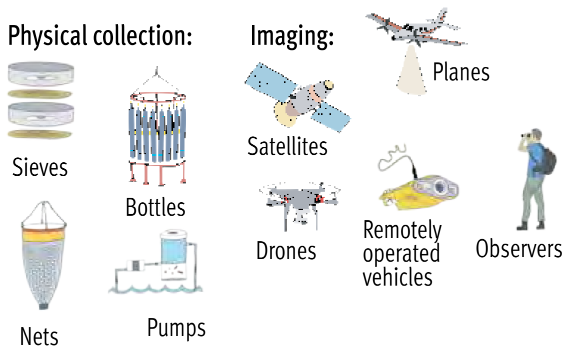
All *SHAPES* and *SIZES* of plastic can be targeted

- *Measure QUANTITY - how much?*
- *Measure litter as DENSITY - use a comparable measure unit*
- *Measure TYPE of litter - category of shape and size*

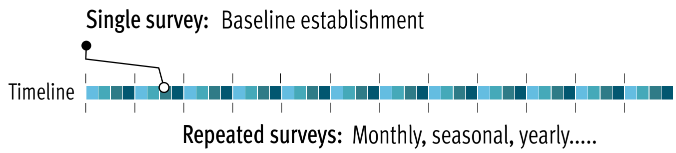


5. Which method?

Depends on the scale and level of detail required



6. When?



7. Who?

Who can collect data for monitoring and assessment

CITIZENS - e.g. participate in documenting derelict fishing gear washed up on beaches

FISHING AND SHIPPING – e.g. report collisions with large debris such as lost containers

SCIENTISTS - research studies, field observations, computer models

NGOs – e.g. volunteers work on dedicated monitoring programmes

WORKERS – e.g. local municipalities carry out monitoring and assessment

GOVERNMENT programmes - e.g. policy development and adjustment according to monitoring results

INDUSTRY – e.g. tracking and reporting losses throughout the production line between differently focused assessments (e.g. assessments designed to understand littering behaviour and those focused on determining transport pathways of litter).

Assessments of marine plastic litter can be undertaken in a number of ways, depending on the objective of the assessment (UNEP 2019). Indicators of pollution can be chosen to measure the state of the environment, such as the amount of plastic in a given environment (e.g per square metre on a beach or in the stomach of a sea bird; Kershaw et al. 2019). Monitoring data are collected to track the indicator. Monitoring programmes can also be designed to collect data on the source, composition, transport pathways, degradation rates and distribution of marine plastic litter. Because of the range of objectives, the monitoring methods employed vary greatly. Monitoring programmes are generally resource intensive and therefore often limited in scale. Lack of monitoring programmes can hinder the development of indicators, the setting of litter reduction targets and the evaluation of policy effectiveness. Having consistent methods of sampling and litter characterization (e.g. size, composition) maximizes the usefulness of collected data and allows for improved data sharing and larger scale analysis (Cheshire et al. 2009). Monitoring also provides an opportunity to promote gender equality in environmental governance; thus it is crucial for governments, intergovernmental bodies, international bodies and the private sector to ensure that both male and female researchers participate in such initiatives, including in decision-making and leadership roles. Moreover, gender-disaggregated data can be collected.

In 2019 the Group of Experts on the Scientific Aspects of Marine Environmental Protection (GESAMP) released a set of guidelines for the monitoring and assessment of plastic litter in the ocean (Kershaw et al. 2019). These guidelines provide practical guidance in developing plastic litter monitoring programmes and support the development of a harmonized system. However, even when similar sampling methods are employed comparisons between assessments may be difficult if other pertinent information is not available (e.g. on wind, currents and land-based sources; Maes and Garnacho 2013).

Monitoring protocols generally include a description of the survey location (e.g. shoreline, sea surface, water column, seafloor, river or biota), classification (e.g. size, function, composition), quantification (e.g. mass per unit of area, number of items per unit of area/volume), methodology for collection (e.g. trawl net), spatial scale and survey frequency. Additional information might include colour, morphological descriptions such as fragment, fibre or pellet, accumulation rate for repeated surveys, and environmental impact.

Monitoring of plastic litter, especially along shorelines, lends itself to public participation. Citizen scientists are involved in many beach and intertidal zone monitoring programmes (Hidalgo-Ruz and Thiel 2015). Citizen science projects like the Australian AUSMAP (2020) map and monitor microplastic pollution. That project is overseen by professional scientists who provide training, field equipment and sampling protocols. The Convention for the Protection of the Marine Environment of the North-East Atlantic (OSPAR) Commission has developed guidelines that provide advice on identifying the type and amount of litter on beaches. It provides reference photographs for classifying common plastic litter items and a monitoring survey form for recording information (OSPAR 2010). Rambonnet et al. (2019) evaluated 10 citizen science plastic pollution monitoring projects and identified key success criteria, which included well-defined project goals, outcome-driven design with a communication and data plan established at the outset, use of well-tested existing protocols to support comparison with other data sets, and engagement and acknowledgment of volunteers.

Because coastal and shallow water areas are the most easily accessible, many plastics sampling and monitoring programmes are concentrated in these areas. However, despite the scale and difficulty of sampling in the open ocean, studies of both surface and subsurface plastic are increasing. It is important to determine the abundance and characterization of plastics in the oceans in order to effectively assess the potential level of exposure of marine organisms to plastic particles and associated chemicals (Koelmans et al. 2017; Isobe et al. 2019).

Although regular monitoring is necessary to access the efficacy of actions being implemented to control marine plastic litter, numerical modelling can also be used to support assessments. Numerical model simulations are used to estimate the sources and fate of litter in the marine environment. Ocean circulation models, combined with information on current, waves, wind and chemical processes, can provide insight into litter dispersion, fragmentation and degradation (Hardesty et al. 2017).

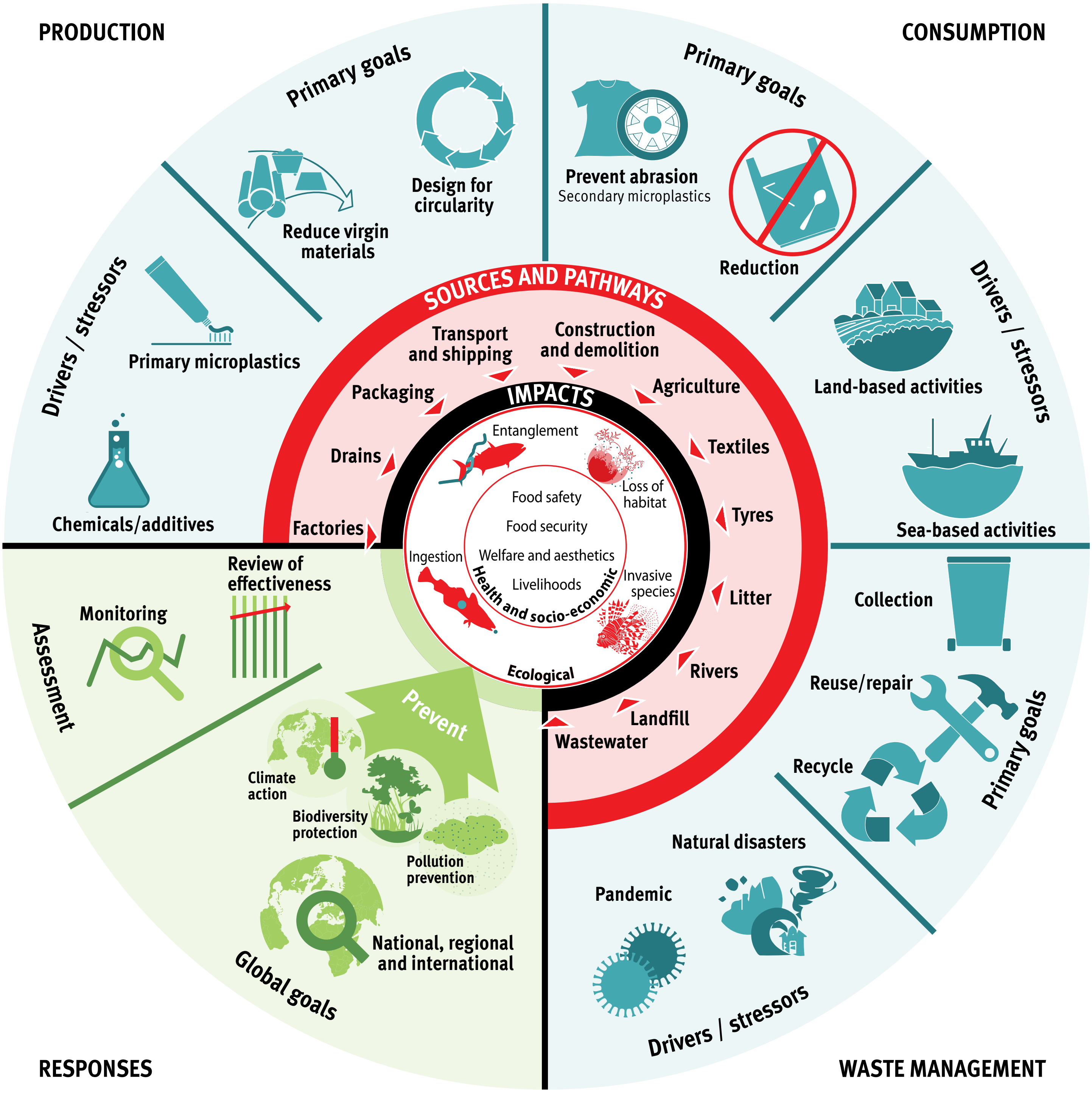
The range of monitoring programmes described can provide information for the design of strategies and actions to prevent and clean up marine litter. These include programmes that target the control of specific problematic litter items (such as single-use plastic bags or polystyrene fishing boxes), locations (e.g. areas identified as zones of accumulation, or sites from which litter is dispersed such as storm water drains), or chemicals that are POPs including some that are also plastic additives (e.g. the global monitoring plan for POPs) (Stockholm Convention 2017).

Taking stock and looking forward

Tacking stock...

The global production of plastics increased from 2 million tonnes in the 1950s to more than 438 million tonnes in 2017 (Geyer 2020), a trend of rapid growth that is expected to continue (PlasticsEurope 2019). The large majority of plastics continue to be made from oil and natural gas (British Plastics Federation 2019). Plastic is all around us, from packaging, smartphones and cosmetics to fishing nets, fertilizers and construction materials. Like all plastic products, these items contain chemical additives. Some of the additives are hazardous to human health and the environment (Stenmarck et al. 2017).

Plastics can escape into the environment at every stage of their life cycle (GESAMP 2016; ISWA 2017; UNEP 2020). To date, around 6.9 billion tonnes of primary plastic waste have been generated and hundreds of millions of tonnes



GRID-Arendal/Studio Atlantis, 2021

are added each year (Geyer 2020). While plastic packaging accounts for a large share of plastic waste, sectors such as fisheries, construction, agriculture, transport and electronics are also significant. Only around 10% of the plastic waste generated to date has been recycled; 14% has been incinerated and 76% has been disposed of in landfills or released into the environment (Geyer 2020). Natural disasters and, recently, the COVID-19 pandemic have intensified pressures of waste management systems, especially in developing countries (WEF 2020). Each year large amounts of plastic waste are exported, often to countries with limited waste management capacities. An alarming increase in the illegal trade of plastic waste has been occurred in recent years (Interpol 2020).

Mismanagement of plastic waste has led to contamination of the entire marine environment, from shorelines to the deepest ocean sediments (e.g. Woodall et al. 2014; Ryan et al. 2016). It has been estimated that approximately 8 million tonnes of plastic waste enter the oceans every year from rivers and land (Jambeck et al. 2015). While precise estimates of inputs from sea-based activities, including fishing and aquaculture, are unavailable, these activities are considered significant sources of marine litter and plastics pollution. Once in the environment, plastics release additives and break down into micro- and nanoplastics (Hahladakis et al. 2018). Among other sources, microplastics are released as a result of abrasion of tyres on road surfaces. Microplastics find their way into wastewater (e.g. due to the use of microbeads in cosmetics and personal care products) and contaminate soils.

Marine litter and plastic waste are a serious environmental problem at a global scale. They have the potential to dramatically shift the ecology of marine systems (Villarrubia-Gomez et al. 2018). Microplastics can have both physical and chemical effects on animals (Galloway et al. 2017). Some plastic additives and persistent waterborne chemicals are capable of activating hormone signal pathways and altering animals' metabolic and reproductive systems (Galloway et al. 2017).

There is concern about the potential of microplastics to adversely affect human health. Plastic particles make their way into the food we eat, the water we drink, and the air we breathe. They can enter the human body through ingestion and inhalation, while nanoplastics may also be able to enter through the skin (Schneider et al. 2009). Plastic particles have become a routine part of the human diet, including through seafood (e.g. Besseling et al. 2015; Digka et al. 2018; Cho et al. 2019; Nelms et al. 2019). What happens to ingested plastic and any associated hazardous chemicals is an area of growing research (Lehner et al. 2019). Considerable economic costs are also associated with marine litter and plastic waste (UNEP 2018).

... and looking forward

Developing a circular plastic economy and limiting plastic pollution require actions by different stakeholders. These stakeholders include waste management and other government authorities, chemical and plastic manufacturers, consumers and companies that produce consumer goods, retailers, waste management operators, plastic recyclers and others, including the informal sector (UNEP 2018; Hahladakis 2020). Moreover, actions are needed at all stages of the life cycle, thereby following the waste management hierarchy and prioritizing waste prevention and minimization.

Many governments have taken initial steps by banning certain single-use plastic packaging and microbeads, implementing extended producer responsibility and deposit-return schemes, and introducing product design standards. Better systems, materials and products need to be designed with the concept of circularity in mind and to reduce the use of hazardous additives. Biodegradable plastics and bioplastics may have potential in this context; however, they currently present a number of challenges and may in some cases even worsen the plastic pollution situation, thus requiring further investment and innovation. Consumer choices, and thus awareness-raising campaigns, are equally important.

Yet it will not be possible to avoid all plastic waste. Strengthened waste management systems and infrastructures covering collection, separation, recycling, recovery and final disposal are needed, especially in developing countries. Such systems require sustainable sources of financing. Policies supporting sustainable end-markets for recyclable materials can drive supply and demand, thereby promoting private sector investment (OECD 2018). Further steps also need to be taken to integrate the informal waste sector (UNEP 2020) and provide equal opportunities to women in plastic waste management (Chikarmane 2012; Aidis and Khaled 2019).

Various international instruments exist to tackle marine litter and plastic waste. The Basel Convention promotes prevention and minimization, environmentally sound management, and control of transboundary movements of plastic waste. The Basel Convention Plastic Waste Amendments are crucial step towards achieving these objectives. The Stockholm Convention plays an important role in addressing the use of certain hazardous additives. Prevention of marine plastic pollution is mandated in the Law of the Sea Convention, MARPOL Annex V, the London Convention and its Protocol. Moreover, a number of UNEA resolutions promote a life cycle approach to the issue and engagement with the private sector (including redesign of products) towards a globally agreed goal of long-term elimination of plastics entering the oceans (UNEA 2017b).

National implementation of these approaches is supported at the regional level by 18 Regional Seas Conventions and Action Plans.

Underpinning these actions is an evidence-based science-policy interface which must be further strengthened through improved monitoring, assessment, and the development of indicators to track national and global progress towards the elimination of plastic pollution from all sources, supported by engagement by all stakeholders at all stages of the life cycle of plastics.

In summary, actions are needed at many levels, at all stages of the life cycle, and by all stakeholders. This publication shows that such actions are feasible and, in many areas, are already underway.

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